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Economic Impacts of Controlling Soil-Loss from Silviculture Activities: A Case Study of Cherokee County, Texas

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ECONOMIC IMPACTS OF CONTROLLING SOIL-LOSS FROM SILVICULTURAL ACTIVITIES: A Case Study of Cherokee County, Texas

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This report, with its many awkward tables and graphs, was patiently and skillfully typed by Janice Mouser, Marijane Kristof, and Cindy Humes.

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INTRODUCTION

Section 208 of the 1972 Amendments to the Federal Water Pollution Control Act (Public Law 92-500) requires the states to develop plans which: (1) contain processes to identify nonpoint sources of pollution, and (2) set forth procedures and methods to control such sources of pollution to the extent feasible.

Among the land use activities which are explicitly identified within Section 208 as potential sources of nonpoint pollution problems is silviculture. Texas, since it contains an estimated 12.5 million acres of commercial forest land (Murphy, 1976), has for some time been actively involved in developing the required planning procedures and materials. This document represents one component of this overall planning process.

The "extent feasible" clause of Section 208 can be interpreted as recognizing the need to consider economic tradeoffs in reaching a decision as to what level of control, if any, should be exercised to limit nonpoint source pollution from whatever type of activity. This would seem to be a reasonable interpretation since it would be illogical to envision extending controls to the point that their marginal costs would exceed their marginal benefits.

Broadly conceived, the purpose of this investigation has been to make a first approximation of the economic tradeoffs that would be associated with any effort to limit the extent of nonpoint pollution resulting from silvicultural activities in Texas. More specifically the study has sought to achieve the following objectives:

1.) To develop a methodology for assessing the economic impacts associated with imposing alternative silvicultural nonpoint source controls at varying intensities.

2.) To demonstrate how the methodology could be applied to a specific study area to facilitate decision-making about the economic rationality of imposing controls.

As the study plan for this project was developed, choices had to be made regarding the range of potential pollutants to consider, the range of alternative control techniques to consider, and the range of economic impacts to consider. Since the nature of these choices represent limitations on the scope of the project, they should be made explicit from the outset.

As regards the range of potential pollutants considered, it is recognized that silvicultural nonpoint source pollution can conceivably assume a variety of forms -- nutrients, chemical, thermal, and so on. Nonetheless, in this investigation sediment is the only potential silvicultural pollutant which has been addressed -- and this only indirectly.[1/] The focal point of the analysis is on the economic impacts of restricting soil loss (i.e. sheet and rill erosion) which is not directly equivalent to sediment yield. Conversion of soil loss figures to sediment yield figures requires knowledge of an appropriate sediment delivery ratio.

While this might appear to be a significant limitation of the study, the investigators are of the opinion that it is not. This conclusion rests upon essentially two facts. First, the bulk of the available evidence pertaining to the potential impacts of silvicultural activities on water quality indicates that in those instances where such activities appear to be creating a problem--

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[1/]It should be recognized that a certain amount of sediment in streamflow is unavoidable and indeed desirable. Recognizing this the State of Texas has not established standards specifying at what level sediment becomes a pollutant sediment is generally the potential pollutant of greatest importance. Secondly, sediment yields will bear a constant proportional relationship to soil loss. Indeed, if the study unit used in this investigation had been a physical watershed instead of a county, the analysis could have dealt directly with sediment yields rather than soil loss.[1/] In turn, if actual sediment yields had been estimated, other potential pollutants could have been introduced into the analysis, if so desired, by the use of appropriate loading functions.

As regards the range of alternative control techniques that might conceivably be used to limit silvicultural nonpoint source pollution, this investigation specifically considers four possibilities. These are: (1) a countywide limit on allowable soil loss, (2) a per acre limit on allowable soil loss, (3) a tax on excess soil loss, and (4) a subsidy for reduced soil loss. While other policy choices undoubtedly exist, these four alternatives are felt to encompass a fairly broad range of possibilities. Accordingly, this limitation on the scope of the study is not perceived to be a serious deficiency.

Finally, as regards the range of economic impacts considered, the present investigation explicitly deals with the impacts of the various alternative control techniques on aggregate income to forest landowners, levels of timber production, and governmental tax revenues or subsidy expenditures. While these items represent a fairly broad range of impacts, they do not completely exhaust the full array of factors which ideally should be considered. Among the relevant variables which have not been dealt with are: (1) off-site damages averted by reduced soil loss and consequent sedimentation, (2) governmental

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[1/] A watershed drains to a single point thus making it possible to calculate a sediment delivery ratio for the area, but such is not the case for a county.

administrative or enforcement costs, (3) indirect or induced economic impacts attributable to an increase or decrease in landowner income or timber output, and (4) the equity implications of silvicultural nonpoint source controls.

Failure to consider the full range of benefits and costs is unquestionably a significant limitation associated with the present investigation. Its practical importance is to complicate the task of drawing inferences about the economic rationality of imposing controls. In this study, time and data limitations were the primary reasons for restricting the range of economic variables considered. In future investigations of this type, if study areas are carefully chosen, it may be possible to estimate off-site damages using a procedure developed by Lee and Guntermann (1976). In addition, Everett and Miller have shown how the indirect or induced economic impacts associated with the imposition of silvicultural controls can be estimated if a regional "Input-Output" model is available for the study area (1975). These types of technical improvements should be introduced in the future. However, it is the opinion of the investigators that the methodology as developed and used in this study can still serve as a valuable aid to rational decision-making.

The techniques that are described in this report entail additional limitations beyond those already identified. Prospective users need to be aware of these limitations, but it is felt that any discussion of them is best deferred until after the methodology itself has been presented. At this point the reader will be in a better position to evaluate their significance.

The material in the remainder of this report has been organized around four chapters. The first describes the study area, giving special attention to the nature of the forest resource base. The second sets forth the methodology for economic impact assessment that was developed as part of this project. The third presents the results obtained by applying the chosen methodology to the selected study unit. Finally, the last chapter sets forth some concluding observations about the remaining methodological limitations previously referred to, future research needs, and the economic rationality of imposing silvicultural nonpoint source controls within the study area.

DESCRIPTION OF THE STUDY AREA

The study unit selected for purposes of this investigation was Cherokee County. There were a number of reasons why this county was chosen, but three were of primary importance. These were: (1) a complete and reasonably recent Soil Survey Report was available for the county, (2) the county is substantially forested, and (3) by East Texas standards the county is relatively hilly. This last consideration was felt to be important given that the primary objective of the study was to estimate the economic tradeoffs associated with the imposition of silvicultural nonpoint source controls. Generally speaking one would expect that nonpoint pollution problems, and consequently the economic tradeoffs associated with controlling them, would be more evident in a county with greater variation in topography.

Location and Physiography

Cherokee County is situated in east-central Texas in what the U. S. Forest Service refers to as the Northeast Texas forest survey region (See Figure 1). The approximate land area of the county is 1,054 square miles, or 674,450 acres (Soil Conservation Service, 1959). The county seat is Rusk.

The prevailing terrain in the county slopes downward from northeast to southeast. Elevation varies from a high of about 700 feet to a low of about 220 feet (Soil Conservation Service, 1959). The northern third of the county is characterized by broad and gently rolling hills. Historically this is where most of the farming activity within the county has been practiced (Soil Conservation Service, 1959). The central portion of the county is also marked by hills, but in general the terrain is much more strongly sloping. There are nearly level

Figure (1). Location of Cherokee County within East Texas pineywoods region. (Earles, 1976) areas scattered throughout the county, but they occur primarily within the flood plains adjacent to the Neches and Angelina Rivers.

As shown in Figure (2), the soils of Cherokee County can be classified into four general catagories: (1) sandy and clayey soils of the flood plains; (2) sandy and clayey soils of the redlands; (3) soils with compact subsoils; and (4) sandy soils with friable subsoils. According to the county Soil Survey Report, the four soil associations represented in the county include over 50 distinct soil types. Most of these soils are medium to strongly acid and have developed from both continental and marine deposits (Soil Conservation Service, 1959).

Climate

The county is one characterized by long warm summers and relatively short mild winters. The mean annual temperature is 66°F and the average frost-free season is 246 days, extending from March 15 to November 16 (Soil Conservation Service, 1959). Precipitation occurs relatively uniformly over the entire county and is fairly well distributed throughout the entire year. Mean annual precipitation runs about 45 inches with virtually all of it being received as rainfall (Soil Conservation Service, 1959).

Current Land Use

Information provided by local Soil Conservation Service personnel indicates that the present pattern of land use within the county is as shown in Table (1). As can be seen, woodland is the predominant land use, accounting for some 59 percent of the total acreage within the county. Pasture land ranks next in importance, accounting for 34 percent. Cropland is relatively unimportant as a land use catagory, accounting for less than 1.0 percent of the total acreage within the county. These figures reflect a quite drastic decline in cropland

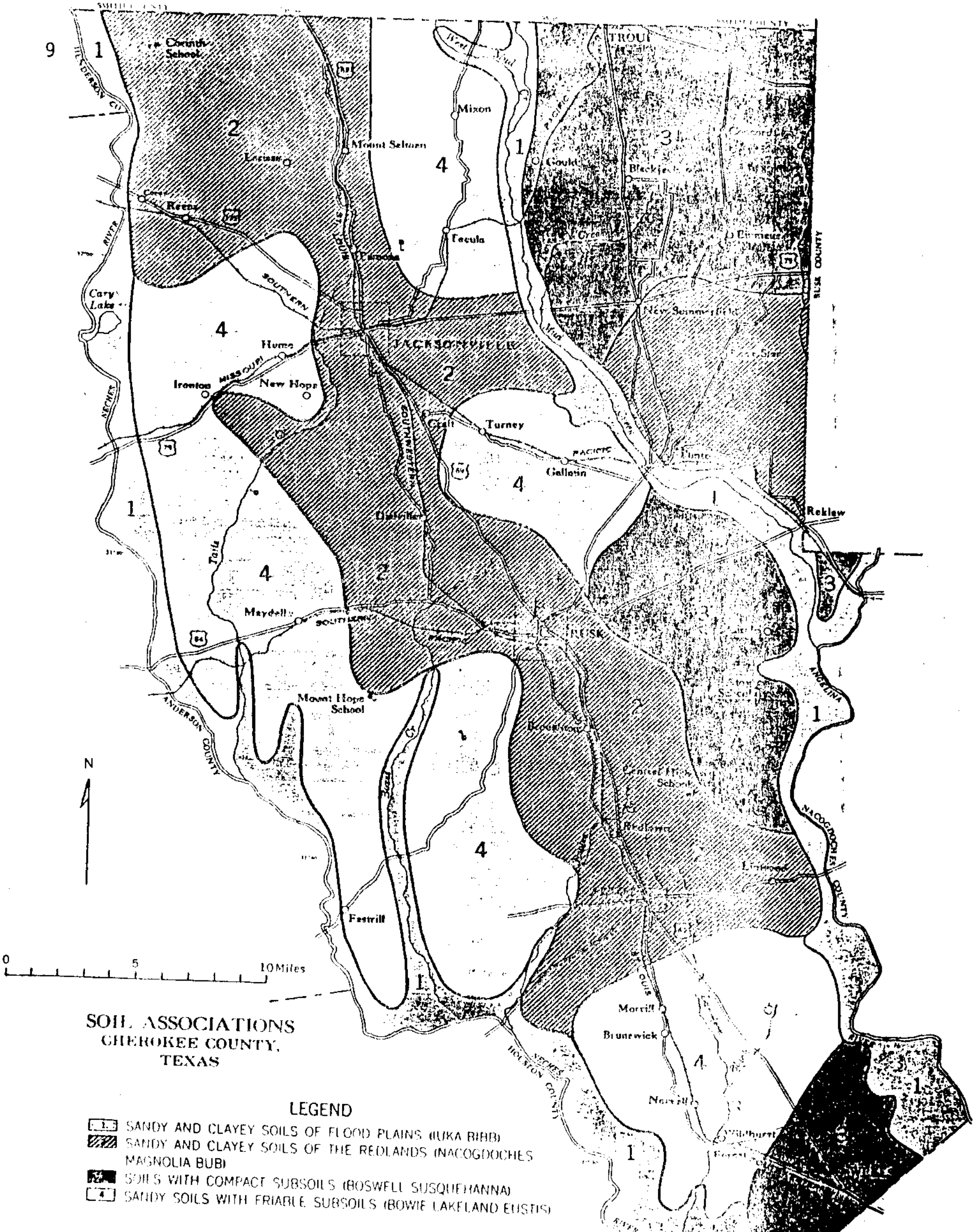

Figure (2). Soil associations found within Cherokee County. (Source: Soil Conservation Service, 1959.)

Table (1). Existing pattern of land uses within Cherokee County.

Land Use	Estimated Acreage
Cropland	4,800
Pasture	
improved	195,500
native	33,400
Woodland	
grazed	237,400
ungrazed	158,300
Large lakes	14,350
Urban, roads, rural homes	30,700
Total	674,450

acreage from the time that the existing county Soil Survey Report was published in 1959. It appears that most of the land once used for cropping has gone into pasture -- but a significant acreage has also apparently been converted to woodland. On that land which is still used for crop production, the principal crops are corn, peanuts, watermelons, milo, and tomatoes and other vegetables.

Forest Resources and Industry

Results from the latest Forest Survey indicate that Cherokee County contains a total of 390,600 acres of commercial forest land (Earles, 1976). In turn, it is estimated that this land base supports a total growing stock volume of 358.1 million cubic feet.[1/] Approximately 61 percent of this growing stock occurs in the form of softwood timber species, principally loblolly and shortleaf pine; the remaining 39 percent occurs as a variety of hardwood timber species, principally oak, hickory, and sweetgum (Earles, 1976). The percentage distributions of both commercial forest acreage and growing stock volume, by both stand size class and ownership class, are as shown in Tables (2) and (3) respectively.

As can be seen from Table (2), whether measured in acreage or volume terms, the timber resources of the county are predominantly in the larger stand size classes. As regards ownership of these resources, Table (3) shows that whether measured in acreage or volume terms, they are almost exclusively under private control. This ownership pattern is rather typical of East Texas, and indeed of the southern pine region in general.

The county is a center of activity for the forest products industry. The most recent industrial directory compiled by the Texas Forest Service indicates that some 15 wood-using plants were in operation within the county during 1977.

[1/] A glossary of technical terms is provided at the end of this report.

Table (2). Percentage distribution of commercial forest acreage and growing stock volume by stand size class within Cherokee County. (Earles, 1976).

Stand Size Class	Comm. Forest Acreage	Growing Stock Volume
Sawtimber	45	68
Poletimber	32	26
Sapling and seedling	23	6
Nonstocked areas	--	--
All classes	100%	100%

Table (3). Percentage distribution of commercial forest acreage and growing stock volume by ownership class within Cherokee County. (Earles, 1976)

Ownership Class	Comm. Forest Acreage	Growing Stock Volume[1/]
National forest	--	--
Other public	1	1
Forest industry	31	34
Farmer	11	10
Misc. private	57	55
All classes	100%	100%

[1/] Estimated by the authors from information contained in the cited reference.

This included 6 sawmills, 4 veneer plants, 4 wood preserving plants, and one miscellaneous wood using company (Texas Forest Service, 1977). Besides the activity generated by these resident firms, many companies in surrounding counties also conduct operations within the study unit. That a highly active timber market exists within the county is evidenced by the fact that in 1976 total industrial roundwood production exceeded 19 million cubic feet (Barron, 1977). While pulpwood, sawlogs, and veneer logs predominated in the product mix; substantial volumes of posts, poles and pilings were also produced.

DESCRIPTION OF STUDY METHODOLOGY

As noted earlier, this study had two principal objectives: (1) to develop a methodolgy that could be used to assess the economic impacts associated with imposing nonpoint controls on silvicultural activities, and (2) to demonstrate how the methodology could be applied to a selected study area to facilitate decision-making about the economic rationality of imposing controls. The purpose of this chapter is to set forth the methodology and show how it was applied to Cherokee County.

Basic Analytical Approach

Given the objectives of the present investigation, it was felt that Linear Programming (LP) constituted an appropriate analytical technique. LP has been used successfully both within the context of agriculture and forestry to conduct studies having similar objectives (Narayanan, Lee, and Swanson, 1974; Everett and Miller, 1975).

The theory and assumptions which underlie the Linear Programming procedure are dealt with in almost any textbook on operations research or mathematical economics, accordingly no attempt is made in this report to discuss them in detail. Suffice it to say that LP is basically a procedure designed to determine the "optimum" allocation of one or more limited resources among two or more alternative competing activities. The "optimum" allocation is defined to be that which either maximizes something, typically profits, or which minimizes something, typically costs. The procedure uses a mathematical model to represent the relationships between the activities and resources included within the system under study. The general form of this model is as follows:

Maximize or Minimize:

$$z = c_1x_1 + c_2x_2 + . . . + c_nx_n$$

Subject To:

$$a_{11}x_1 + a_{12}x_2 + . . . + a_{1n}x_n \ (\leq, =, \geq) \ b_1$$
$$a_{21}x_1 + a_{22}x_2 + . . . + a_{2n}x_n \ (\leq, =, \geq) \ b_2$$
$$\vdots$$
$$a_{m1}x_1 + a_{m2}x_2 + . . . + a_{mn}x_n \ (\leq, =, \geq) \ b_m$$

and:

$$x_1 \geq 0, \ x_2 \geq 0, \ . . ., \ x_n \geq 0.$$

Where:

z = the "overall measure of effectiveness", the variable whose value you are seeking to maximize or minimize.

x_j = the level of operation of the jth activity. In this generalized model $j = 1, 2, . . . , n$ implying the existence of n alternative competing activities.

c_j = the coefficient indicating the change in z that will occur as a result of a one unit change in the level of operation of the jth activity. In this generalized model $j = 1, 2, . . . , n$.

b_i = the amount available of the ith limited resource. In this generalized model $i = 1, 2, . . ., m$ implying the existence of m limiting resources.

a_{ij} = the amount of the ith resource consumed per unit level of operation of the jth activity.

The function being maximized or minimized is referred to as the "objective function". Within the context of any given problem the objective will be either maximization or minimization -- not both simultaneously. The set of functions describing levels of resource availability and rates of resource usage are referred to as "constraints" or "restrictions". Within the context of any given problem only one functional relationship -- less than or equal to, equal to, or greater than or equal to -- will apply to a particular constraint. Those constraints which are of the form $x_j \geq 0$ are referred to as "non-negativity constraints", their effect is to preclude the activities within the model from assuming negative levels of operation. Using this framework the Linear Programming procedure will determine at what level the n competing activities (x_j's) should be operated in order to maximize or minimize the value of the objective function while simultaneously adhering to all of the resource limitations implied by the set of constraints.

In order to begin to envision how the Linear Programming procedure could be used to study the economic tradeoffs associated with the imposition of silvicultural nonpoint controls, one must recognize that two of the variables of primary concern -- soil loss and the income received by forest landowners -- are themselves both largely determined by two other factors: (1) soil type, and (2) the type of forestry practices employed. Soils differ in terms of their potential to grow crops of wood and also in terms of their potential for erosion. Similarly, the type of forest management practices employed will influence timber output and the potential for soil loss. In view of these inter-relationships we can envision setting-up another Linear Programming model, but one in which the variables take on specific meanings relevant to the problem with which we are concerned. Such a model is set forth below:

Maximize:

$$z = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij}$$

Subject To:

$$\sum_{j=1}^{n} x_{ij} = b_i \quad \text{for } i = 1, 2, \ldots, m$$

$$\sum_{i=1}^{m} \sum_{j=1}^{n} a_{ij}x_{ij} \; (=, \leq) \; L$$

and:

$$x_{ij} \geq 0$$

Where:

z = annual income received from forest management activities by all forest landowners within study unit. (Note: while forestry is the type of activity that does not normally provide an annual income, procedures exist for expressing periodic incomes in terms of annual equivalents.)

x_{ij} = number of acres of soil type i managed under forest management system j. In this generalized model i = 1, 2, . . ., m implying the existence of m distinct soil types and j = 1, 2, . . ., n implying the existence of n alternative forest management systems. (Note: ideally the alternative forest management systems should be defined to cover a broad range from essentially no forest management to a highly intensive form of management. If the options are defined in this way they should encompass the full range of possibilities for generating both income and soil loss.)

c_{ij} = annual income received from managing one acre of soil type i under forest management system j. (Note: in general we would expect annual income to increase as the intensity of forest management increases. It would also increase as soil productivity improved.)

b_i = number of acres of soil type i available in the study area. Since i = 1, 2, . . ., m there would be m such constraints in the model.

a_{ij} = amount of soil loss in tons per acre per year that results from managing one acre of soil type i under forest management system j. (Note: in general we would expect soil loss to increase as the intensity of management increases because this would mean more frequent disturbance of the site. Soil loss would also be expected to increase on more erodible soils.)

L = total annual soil loss experienced over the entire study unit. (Note: total annual soil loss can be entered into the model as a constraint, in which case the less than or equal to functional relationship would be relevant; or it can be treated as a nonconstraining variable, in which case the strict equality would be the relevant functional relationship.)

The preceding is a generalized statement of the model that has been applied to Cherokee County in order to estimate the economic impacts that would result from applying silvicultural nonpoint source controls. Before the specific model utilized in the study can be set forth, a number of questions must be answered. These include: (1) what are the relevant timber management alternatives for the study area, (2) what are the specific soil types encountered within the study area, (3) what soil loss can be expected to result from applying a particular timber management system on a particular soil type, and (4) what annual return can be expected to result from applying a particular timber management system on a particular soil type. The procedures that were utilized to answer these questions are detailed in the subsequent subsections of this chapter. This is then followed by a statement of the specific LP model used in this investigation.

Identifying Timber Management Options

The alternative timber management systems recognized in this study were developed in consultation with forest management and silviculture specialists from the Department of Forest Science at Texas A&M University. The alternatives were constructed to encompass a very broad range of possible management intensities. Furthermore, since Forest Survey statistics indicated that the commercial forest land base of Cherokee County can be classified into two distinct physiographic site classes -- 346,500 acres in pine and 44,100 acres in bottomland hardwood -- both pine management and hardwood management options were identified (Earles, 1976).

Pine Management Options.

The pine management options recognized in the analysis are described in Table (4). All presume that loblolly pine will be the preferred species.

The short rotation pine plantation option represents the most intensive form of management recognized in this analysis. Following removal of the existing stand it is assumed that the harvest area will be site prepared and planted. Initially site preparation will probably be accomplished by shearing with a KG blade. The residual material left on-site will then be raked into windrows and burned. Planting will be accomplished by machine and genetically improved planting stock will be used. It is assumed that 908 trees will be planted per acre; this would correspond to a 6 X 8 spacing pattern. At age 10 a prescribed burn will be conducted to reduce vegetative competition and the risk of wildfire. At age 15 a commercial thinning will be conducted to remove pulpwood sized material while simultaneously stimulating growth on the residual stems; at the same time the stand will be burned for the second time. At age 20 a third and final prescribed burn will be conducted. At age 25 the stand will be clearcut harvested and the cycle will begin to repeat itself. It has been assumed that in subsequent rotations less intensive methods of site preparation, such as roller chopping, will be utilized. This particular option is felt to represent the type of management industry could be expected to apply on its best quality sites.

The medium rotation pine plantation option also represents a quite intensive form of management. Site preparation and planting are accomplished by the same means as for the short rotation pine plantation. Again it is assumed that

Table (4) Pine management options recognized in LP model.

Year	Short Rotation Plantation	Medium Rotation Plantation	Long Rotation Plantation
0	Site prep, burn and plant	Site prep, burn and plant	Site prep, burn and plant
5	--	--	--
10	Prescribed burn	--	Prescribed burn
15	Commercial thin and burn	Commercial thin and burn	--
20	Prescribed burn	--	Commercial thin and burn
22	--	Commercial thin and burn	--
25	Harvest	--	--
29		Commercial thin	--
30		--	Prescribed burn
35		Harvest	Commercial thin
40			Prescribed burn
45			--
50			Commercial thin and burn
55			--
60			Harvest

Table (4). Continued.

Year	Short Rotation Natural Stand Management	Long Rotation Natural Stand Management
0	--	--
5	Precommercial thin	Precommercial thin
10	--	--
15	Commercial thin and burn	Prescribed burn
20	--	Commercial thin
25	Commercial thin and burn	Prescribed burn
30	--	--
35	Harvest	Prescribed burn
40		Commercial thin
45		Prescribed burn
50		--
55		Prescribed burn
60		Commercial thin
65		--
70		Harvest

genetically improved planting stock will be used. A regular program of prescribed burns and commercial thins are stipulated as part of the management routine. In this instance, however, a final harvest cut is not made until age 35. This particular option is felt to be representative of the type of management industry would practice on its better than average sites.

The long rotation pine plantation option, since it does represent a plantation form of management, must also be considered as one of the more intensive management options. Site preparation and planting are accomplished by the same means as for the other plantation schemes, but in this instance it has not been assumed that genetically improved planting stock would be utilized. This option, by comparison to the other plantation options, is geared to the production of sawlog rather than pulpwood sized material. The alternative is felt to be fairly representative of the type of management that might be applied on the better quality publically owned lands.

The two remaining pine management options are felt to represent fairly intensive forms of natural stand management; the short rotation system being geared to the production of softwood pulpwood and the long rotation system to the production of softwood sawtimber. Since natural regeneration is relied upon, the site preparation and planting activities associated with the plantation options are no longer necessary. However, in order to prevent early stagnation, and to gain some control over initial stand spacing, a precommercial thinning must now be conducted at age 5. As with the other pine management options a regular program of commercial thinnings and prescribed burns is maintained throughout the life of the stand. Final harvest cuts come at age 35 for the short rotation option and age 70 for the long rotation option. These cuts would be made using relatively small clearcut blocks or by leaving seedtrees.

Hardwood Management Options.

The hardwood management options recognized in the analysis are described in Table (5). Both presume that sweetgum will be the preferred species. Only two options were developed because it was recognized that the East Texas timber market is overwhelmingly geared to the production and consumption of pine.

Both of the recognized hardwood options involve the management of natural stands. The short rotation alternative is felt to represent the most intensive form of hardwood management likely to be practiced on private lands while the long rotation option is felt to be characteristic of what might be done on public lands. Both alternatives call for a weeding or release cut at age 10 and two subsequent commercial thinnings. The timing of the thinnings depends on the length of the rotation. The final harvest cut occurs at age 50 for the short rotation option and age 80 for the long rotation. It is assumed this final harvest will be accomplished using a patch clearcut system.

Other Management Options.

To round-out the array of management alternatives, two other possibilities were recognized. These were: (1) a custodial management option, and (2) an undisturbed forest option. The custodial management option is interpretated to imply no forest management except for forest protection (i.e. primarily against fire) and harvesting. It is assumed that the harvest operations will be conducted at approximately 20 year intervals and that they will be selective cuts which remove primarily sawtimber sized material. The undisturbed forest option, as the name implies, involves absolutely no forest management except possibly for protection purposes. Both of these alternatives are felt to be reasonably descriptive of the type of management, if indeed it can be called that, which is practiced by many private non-industrial woodland owners.

Table (5). Hardwood management options recognized in LP model.

Year	Short Rotation Natural Stand Management	Long Rotation Natural Stand Management
0	--	--
5	--	--
10	Weeding or release cut	Weeding or release cut
15	--	--
20	Commercial thin	--
25	--	--
30	--	Commercial thin
35	Commercial thin	--
40	--	--
45	--	--
50	Harvest	Commercial thin
55		--
60		--
65		--
70		--
75		--
80		Harvest

Such owners may or may not be interested in the income producing potential of their woodland, but typically they are unwilling to make long-term capital investments in timber management.

In total these nine options are felt to encompass the full range of forest management alternatives -- from high intensity to low intensity -- which are relevant to Cherokee County. Indeed they probably include most of the basic alternatives relevant to the entire East Texas region. In this analysis it has been assumed that the pine management options would only be applied on soils in the pine physiographic site class and the hardwood options on soils in the bottomland hardwood physiographic site class. By comparison, the custodial management and undistrubed forest options have not been so restricted-- it has been assumed that these alternatives can be applied on any soil.

Assembling Required Soils Information

As implied earlier, a tremendous amount of soils information is required for a study of this nature. This stems from the fact that soils will influence the two variables of central interest in the analysis -- soil loss and the income to be derived from forest management. Variations in soil loss will be attributable, at least in part, to variation in the potential erodibility of different soils. By similar reasoning, variations in forestry income will be attributable, at least in part, to variation in the potential productivity of different soils.

The procedures for estimating soil loss and timber yields under each of the possible alternative management options are discussed in subsequent sections of this chapter. The purposes of this section are simply to: (1) set forth the basic soils information for Cherokee County, and (2) show how this information must be aggregated to apply the proposed methodology.

The basic reference source used to identify the soils which occur within the study unit was the published Soil Survey Report for Cherokee County. However, since the survey report for this county had been published some time ago (1959), and since the names of many of the soil series had subsequently been changed, personnel of the Soil Conservation Service were asked to provide a new soils listing showing the currently accepted name for each soil. This listing is provided in Table (6). The table also identifies the acreage of each soil found within the county and the types of land use -- cropland, pastureland, forestland -- currently practiced on each type of soil.

In Table (6) the individual soils have been organized into 20 "Soil Management Groups".[1/] In this investigation it is these "Soil Management Groups", rather than the individual soils themselves, that have been used as the basic analytical unit for determining the variable impact of soils on soil loss and timber yields. The rationale for doing this was to limit somewhat the size of the LP model required to perform the desired analysis. The number of "Soil Management Groups" containing soils used for timber growing is only 18 (Note: the soils in Soil Management Groups 19 and 20 are not used for forestry purposes.). By comparison, the number of individual soils so used is 58. If one accepts the soils themselves as the basic soil unit upon which the various forest management options are to be applied, the number of possible "management option - soil management group" combinations becomes quite large.

Having accepted the various Soil Management Groups as the basic unit for differentiating soils, two additional steps were then taken before any effort was made to estimate soil loss or timber yields. First, the various Soil Management Groups were classified into either the pine physiographic site class or the bottomland hardwood physiographic site class. This was done on the basis

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[1/] A soil management group is defined as a set of soils that will grow similar crops and which have similar management needs.

Table (6). Acreage and use of different soils found within Cherokee County. (Source: Data provided by Soil Conservation Service.)

Soil	Acreage	Current Land Use Crops	Pasture	Forest
Soil Management Group (1)[1/]				
Woden	1,000	X	X	X
Soil Management Group (2)				
Bowie fsl g.s.	16,800	X	X	X
Elrose fsl g.s.	7,700	X	X	X
Nacogdoches fsl g.s.	7,700	X	X	X
Nacogdoches cl g.s.	500	--[2/]	X	X
Ruston fsl	2,000	X	X	X
Soil Management Group (3)				
Lilbert lfs g.s.	11,600	X	X	X
Briley lfs g.s.	2,900	X	X	X
Soil Management Group (4)				
Bowie fsl s.	40,500	--	X	X
Elrose fsl s.	25,800	--	X	X
Nacogdoches fsl s.	19,200	--	X	X
Ruston fsl s.	5,000	X	X	X
Soil Management Group (5)				
Lilbert lfs s.	42,500	X	X	X
Briley lfs s.	7,700	X	X	X
Soil Management Group (6)				
Sacul fsl g.s.	3,700	--	X	X
Woodtell fsl g.s.	6,100	--	X	X
Soil Management Group (7)				
Bowie fsl s.e.	1,200	--	X	X
Cuthbert fsl s.	800	--	X	X
Ruston fsl s.e.	300	X	X	X
Soil Management Group (8)				
Sacul fsl s.	42,800	--	X	X
Nacogdoches fsl s.e.	14,500	--	X	X
Nacogdoches cl s. & s.e.	900	--	X	X

Table (6). Continued.

Soil	Acreage	Current Land Use Crops	Pasture	Forest
Soil Management Group (9)				
Betis lfs n.l.	9,200	X	X	X
Bienville lfs	3,600	X	X	X
Bienville lfs n.l.	8,500	X	X	X
Darco lfs n.l.	7,800	X	X	X
Soil Management Group (10)				
Betis lfs s.	19,800	X	X	X
Bienville lfs s.	1,400	X	X	X
Darco lfs s.	21,500	--	X	X
Soil Management Group (11)				
LaCerda cl	1,400	--	X	X
LaCerda cl g.s.	4,000	X	X	X
Soil Management Group (12)				
Lilbert lfs s.e.	1,900	X	X	X
Betis lfs s.e.	200	X	X	X
Darco lfs s.e.	100	--	X	X
Soil Management Group (13)				
Sacul fsl s.e.	3,800	--	X	X
Sacul fsl s.s. & s.s.e.	50,650	--	X	X
Sacul scl s.s. & s.e.	200	--	X	X
Bub-Trawick complex	37,600	--	--	X
Cuthbert fsl s.s. & s.s.e.	21,800	--	X	X
Trawick s.s.	40,200	--	X	X
Trawick s.s.e.	8,000	--	X	X
LaCerda cl s.	900	X	X	X
LaCerda c n.l.	400	X	X	X
Woodtell fsl s. & s.e.	4,400	--	X	X
Soil Management Group (14)				
Darco lfs s.s. & s.s.e.	12,200	--	X	X
Bienville lfs s.s.	600	X	X	X
Darco lfs s.s.	14,500	--	X	X
Tenaha s.s.	14,200	--	X	X

Table (6). Continued.

Soil	Acreage	Current Land Use Crops	Pasture	Forest
Soil Management Group (15)				
Tuscosso fsl	15,200	X	X	X
Iuka fsl	34,100	--	X	X
Bienville lfs	2,200	X	X	X
Soil Management Group (16)				
Tuscosso cl	900	--	X	X
Marietta cl	13,700	--	X	X
Soil Management Group (17)				
Alazan fsl	6,800	--	X	X
Alazan mound	400	--	X	X
Soil Management Group (18)				
Mantachie cl	33,100	--	--	X
Mantachie fsl	5,800	--	X	X
Percilla soils	4,600	--	X	X
Soil Management Group (19)				
Alto cl	3,900	--	X	--
Alto l	400	--	X	--
Soil Management Group (20)				
Marsh	1,400	--	--	--

[1]The soils included within each Soil Management Group correspond to those identified in the Cherokee County Soil Survey Report but the actual numbers assigned to the various groups have been changed.

[2]Indicates the soil in question is not presently used for the specified type of land use.

of information from the Soil Survey Report which characterized the various soils in terms of such items as internal drainage, native vegetation, and suitable uses. In all instances there was little difficulty in determining if a soil was an upland or bottomland soil. Secondly, the acreage of commercial forest land within each Soil Management Group was estimated. This was done by using the sequence of steps outlined below.

1.) For each physiographic site class, calculate the total acreage of all Soil Management Groups included within the class.

2.) For each physiographic site class, express the acreage within each Soil Management Group as a percentage of the total acreage in the class.

3.) Determine the actual acreage of commercial forest land within each physiographic site class. This information can be obtained from the Forest Survey statistics published by the U. S. Forest Service.

4.) For each physiographic site class, multiply the percentages calculated in step (2) by the acreage figures determined in step (3). The product will be the required estimate of the number of acres of commercial forest land in each Soil Management Group. The estimate will be based upon the assumption that within a particular physiographic site class, the percentage distribution of the various Soil Management Groups throughout the commercial forest land base will be the same as their distribution throughout the site class as a whole.

Table (7) shows for each of the Soil Management Groups in Cherokee County, the appropriate physiographic site class and the estimated acreage in commercial forest land. Given the assumptions made earlier as to which forest management options could be employed on which types of soils, it can now be seen that our

Table (7). Physiographic site class and commercial forest acreage of Soil Management Groups found in Cherokee County.

Soil Management Group	Physiographic Site Class	Acreage
Soil Management Group (1)	Pine	624
Soil Management Group (2)	Pine	21,864
Soil Management Group (3)	Pine	9,148
Soil Management Group (4)	Pine	56,999
Soil Management Group (5)	Pine	31,636
Soil Management Group (6)	Pine	6,168
Soil Management Group (7)	Pine	1,455
Soil Management Group (8)	Pine	36,660
Soil Management Group (9)	Pine	18,364
Soil Management Group (10)	Pine	26,888
Soil Management Group (11)	Pine	3,396
Soil Management Group (12)	Pine	1,386
Soil Management Group (13)	Pine	105,786
Soil Management Group (14)	Pine	26,126
Soil Management Group (15)	Bottomland Hardwood	19,444
Soil Management Group (16)	Bottomland Hardwood	5,512
Soil Management Group (17)	Bottomland Hardwood	2,721
Soil Management Group (18)	Bottomland Hardwood	16,423
Total		390,600

final Linear Programming model will include a total of 114 distinct activities. These consist of 5 pine management options that can be applied on any of 14 pine soil management groups; 2 hardwood management options that can be applied on any of 4 bottomland hardwood soil management groups; a custodial management option that can be applied on any of the 18 soil management groups; and an undisturbed forest management option that can also be applied on any of the 18 soil management groups.

Estimating Soil Losses

One of the essential pieces of information required for the Linear Programming analysis are estimates of the soil loss that will occur as a consequence of applying a particular forest management option on a particular soil management group. These data constitute the activity coefficients of the soil loss constraint in the LP model. In this study, the required estimates were formulated by using the Universal Soil Loss Equation (USLE) developed by Wischmeier and Smith. This equation states:

$$A = RKLSCP$$

Where:

A = the computed soil loss (i.e. sheet and rill erosion) in tons per acre per year. As noted earlier, A is not equivalent to sediment yield.

R = the rainfall factor; it is the number of erosion-index units in a normal year's rain. The erosion index is a measure of the erosive force of specific rainfall.

K = the soil-erodibility factor; it is the erosion rate per unit of erosion index for a specific soil in cultivated continuous fallow, on a 9-percent slope 72.6 feet long.

L = the slope-length factor; it is the ratio of soil loss from the field slope length to that from a 72.6 foot length on the same soil type and gradient

S = the slope-gradient factor; it is the ratio of soil loss from the field gradient to that from a 9-percent slope.

C = the cropping-management factor; it is the ratio of soil loss from a field with specified cropping and management to that from the fallow condition on which the K factor is evaluated.

P = the erosion-control practice factor; it is the ratio of soil loss assuming some type of soil conservation measure such as contouring, terracing, or stripcropping to that which would occur with straight-row farming up and down slope. (Wischmeier and Smith, 1965)

It must be noted that the accuracy of the Universal Soil Loss Equation as a method for predicting the soil losses that will occur in forested watersheds leaves much to be desired. The equation was developed to apply to agricultural watersheds which from a hydrologic standpoint can be expected to behave quite differently from their forested counterparts. In spite of efforts to modify the equation to make it more applicable to woodland conditions, the quality of soil loss predictions remains suspect. To illustrate, Dissmeyer and Stump, in discussing the use of the equation to predict soil losses from various forestry activities, state: " . . . these are <u>predicted</u> values and should be used as <u>indexes</u>, not as the gospel truth. The Universal Soil Loss Equation predicts long-term (50 year) average rates with an accuracy of plus or minus 100 percent. The rates predicted should be viewed as ball park figures." (1977)

While the shortcomings of the Universal Soil Loss Equation were recognized and appreciated, it was still chosen as the means for estimating soil losses in this study. This was largely unavoidable since the present state-of-the-art in soil loss prediction offers few viable alternatives.

Information pertaining to the appropriate values to use for the variables in the Universal Soil Loss Equation was obtained from a number of sources. The rainfall factor (R) was determined from an "iso-erodent map" in the publication "Procedure for Computing Sheet and Rill Erosion on Project Areas" (Soil Conservation Service, 1977). For Cherokee County the appropriate value of R appears to be on the order of 375. The values of the soil erodibility (K), slope-length (L), and slope-gradient (S) factors were provided by the Soil Conservation Service for all of the soils in the study area.[1/] Since the basic soil unit in the Linear Programming model was to be the Soil Management Groups, an average K and LS value had to be computed for each such group. This was done by taking a weighted average of the K and LS values for all soils in each Soil Management Group. The weights used were the acreages of each soil in each Soil Management Group. To illustrate, the computations for Group (4) are summarized in Table (8). Application of this procedure to all of the Soil Management Groups in the study area produced the figures displayed in Table (9).

When attempting to predict soil losses from forested watersheds, the cropping-management (C) and erosion-control practice (P) factors are generally the most difficult components of the Universal Soil Loss Equation to estimate. For purposes of this investigation, the set of "CP" factors shown in Table (10) were used as basic input data. These figures purport to be representative of East Texas Coastal Plain conditions and they cover essentially the full range of forest practices recognized in the various management options that were previously defined.

[1/] The specific values of K, LS, and T for each individual soil in Cherokee County are provided in Appendix A.

Table (8). Determination of average K and LS values for Soil Management Group (4).

Soil	Acreage	K Value[1/]	LS Value
Bowie fsl s.	40,500	.14	1.07
Elrose fsl s.	25,800	.11	.47
Nacogdoches fsl s.	19,200	.14	.65
Ruston fsl s.	5,000	.14	.43
Total	90,500		

$$\text{Avg. K} = \frac{40{,}500(.14) + 25{,}800(.11) + 19{,}200(.14) + 5{,}000(.14)}{90{,}500} = .14$$

$$\text{Avg. LS} = \frac{40{,}500(1.07) + 25{,}800(.47) + 19{,}200(.65) + 5{,}000(.43)}{90{,}500} = .77$$

[1/]The published K values provided by the Soil Conservation Service were multiplied by .45 to account for the fact that forest soils are not regularly tilled and consequently are less readily erodible. (Dissmeyer and Foster, 1977)

Table (9). Average K and LS values for the Soil Management Groups in Cherokee County.

Soil Management Group	Avg. K Value	Avg. LS Value
Soil Management Group (1)	.09	.11
Soil Management Group (2)	.14	.32
Soil Management Group (3)	.09	.21
Soil Management Group (4)	.14	.77
Soil Management Group (5)	.09	.56
Soil Management Group (6)	.18	.21
Soil Management Group (7)	.14	1.50
Soil Management Group (8)	.14	.87
Soil Management Group (9)	.08	.23
Soil Management Group (10)	.08	.69
Soil Management Group (11)	.14	.23
Soil Management Group (12)	.09	.63
Soil Management Group (13)	.15	2.83
Soil Management Group (14)	.08	1.53
Soil Management Group (15)	.12	.08
Soil Management Group (16)	.13	.07
Soil Management Group (17)	.19	.12
Soil Management Group (18)	.13	.11

Table (10). CP factors for selected forest practices applied in the Coastal Plain of East Texas. (Source: unpublished data provided in 1977 by George E. Dissmeyer, Forest Hydrologist, USFS, Atlanta, Georgia 30309.[1])

Forest Practices	CP Factors (1-4 years after treatment) (1)	(2)	(3)	(4)
Undisturbed forest	0.0007			
Grazed forest	0.004			
Clearcut harvesting	0.0046	0.0048	0.001	--
Chopping	0.0092	0.005	0.0003	--
Chop and burn	0.015	0.008	0.002	--
Prescribed burning	0.006	0.005	--	--
Shearing, K-G	0.031	0.013	0.007	0.004
Disk	0.06	0.095	0.04	0.01
Bedding	0.039	0.002	0.001	--
Dozing	0.032	0.034	0.007	0.002
Logging[2]	0.0091	0.0091	0.0091	--

[1] CP factors for forest practices in the Southern Coastal Plains are just now being developed. The figures provided in this table, while they represent the present state-of-the-art, are based on extremely limited field observations. Much research is needed before these figures receive broad use.

[2] The CP factor for logging was estimated by the authors. Dissmeyer and Stump (1977) report that in the Coastal Plain of East Texas sampled logging operations resulted in an average soil loss of .52 tons/ac./yr. with a recovery period of 3 years. Within Cherokee County the average K and LS values, over all soil types, are .126 and 1.21 respectively. Knowing that R = 375 it becomes possible to solve the soil loss equation for CP. We have:

$$A = RKLSCP \text{ or } .52 = 375(.126)1.21(CP)$$

$$CP = \frac{.52}{375(.126)1.21} = .0091$$

In order to arrive at the desired estimate of the amount of soil loss that would result from applying a particular management option on a particular soil management group, an average CP factor had to be calculated for each management option. This was conceptually possible given that we knew: (1) the nature and timing of the forest practices employed in connection with each management option, and (2) the specific values of CP for differnet forest practices at different points in time. The procedure is illustrated in Table (11) for the Short Run Pine Plantation option. The average CP values that were derived for all the relevant management options are displayed in Table (12).

At this juncture all the information needed to calculate the desired soil loss figures has been compiled. The value of the rainfall factor is 375; the values of K and LS, for each soil management group, are given in Table (9); and the values of CP, for each forest management option, are given in Table (12). Applying the Universal Soil Loss Equation to each feasible "management option-soil management group" combination yields the estimated annual soil loss figures shown in Table (13).

Estimating Annual Net Returns

The second essential piece of information required for the Linear Programming analysis are estimates of the annual net income that will be obtained by applying a particular forest management option on a particular soil management group. These data constitute the required activity coefficients in the objective function. Essentially 4 steps are required to obtain the annual net return estimates. These are:

1.) Prediction of the timber yields that would be obtained under each forest management option-soil management group combination.

2.) Estimation of the dollar value of the predicted timber yields. This requires knowledge of current market prices for roundwood timber products.

Table (11). Determination of average CP factor for the short rotation pine plantation management option.

Year	Management Practice	CP	Explanation
0	Site prep., burn and plant	.031	Shearing, KG -- yr. 1[1/]
1	--	.013	Shearing, KG -- yr. 2
2	--	.007	Shearing, KG -- yr. 3
3	--	.004	Shearing, KG -- yr. 4
4	--	.004	Grazed forest[2/]
5	--	.004	Grazed forest
6	--	.004	Grazed forest
7	--	.004	Grazed forest
8	--	.004	Grazed forest
9	--	.004	Grazed forest
10	Prescribed burn	.006	Prescribed burn -- yr. 1
11	--	.005	Prescribed burn -- yr. 2
12	--	.004	Grazed forest
13	--	.004	Grazed forest
14	--	.004	Grazed forest
15	Commercial thin and burn	.0091	Logged for thinning
16	--	.0091	Logging effects -- yr. 2
17	--	.0091	Logging effects -- yr. 3
18	--	.004	Grazed forest
19	--	.004	Grazed forest
20	Prescribed burn	.006	Prescribed burn -- yr. 1
21	--	.005	Prescribed burn -- yr. 2
22	--	.004	Grazed forest
23	--	.004	Grazed forest
24	--	.004	Grazed forest
25	Harvest	.0091	Logged for final harvest
	Total	.1654	

Average CP factor over length of entire rotation is calculated as follows:

$$\text{Avg. CP} = \frac{.1654}{25} = .0066.$$

[1/] When two or more activities are performed in the same year the highest CP factor is utilized.

[2/] CP value for grazed forest was used since the majority of forest land in Cherokee County is grazed.

Table (12). Average CP factors for the alternative forest management options.

Management Option	Average CP
Short rotation pine plantation	.0066
Medium rotation pine plantation	.0061
Long rotation pine plantation	.0056
Short rotation pine natural stand	.0059
Long rotation pine natural stand	.0054
Short rotation hardwood natural stand	.0053
Long rotation hardwood natural stand	.0048
Custodial management	.0050
Undisturbed forest	.0007

Table (13). Predicted average annual soil loss for all feasible management option-soil management group combinations. (Tons/Ac./Yr.)

Management Options	Soil Management Groups #1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15	#16	#17	#18
Short rotation pine plantation	.0245	.1109	.0468	.2668	.1247	.0936	.5198	.3015	.0455	.1366	.0797	.1403	1.0507	.3029	--	--	--	--
Medium rotation pine plantation	.0226	.1025	.0432	.2466	.1153	.0865	.4804	.2786	.0421	.1263	.0737	.1297	.9711	.2800	--	--	--	--
Long rotation pine plantation	.0208	.0941	.0397	.2264	.1058	.0794	.4410	.2553	.0386	.1159	.0676	.1191	.8915	.2570	--	--	--	--
Short rotation pine natural stand	.0219	.0991	.0418	.2385	.1115	.0837	.4646	.2695	.0407	.1221	.0713	.1254	.9392	.2708	--	--	--	--
Long rotation pine natural stand	.0200	.0907	.0383	.2183	.1021	.0766	.4252	.2457	.0373	.1118	.0652	.1148	.8596	.2479	--	--	--	--
Short rotation hardwood natural stand	--	--	--	--	--	--	--	--	--	--	--	--	--	--	.0191	.0181	.0453	.0284
Long rotation hardwood natural stand	--	--	--	--	--	--	--	--	--	--	--	--	--	--	.0173	.0164	.0410	.0257
Custodial management	.0185	.0840	.0354	.2021	.0945	.0709	.3938	.2284	.0345	.1035	.0604	.1063	.7959	.2295	.0180	.0170	.0428	.0262
Undisturbed forest	.0026	.0118	.0050	.0283	.0132	.0099	.0551	.0320	.0048	.0145	.0085	.0149	.1114	.0321	.0025	.0024	.0050	.0038

3.) Estimation of the production costs associated with each timber management option.

4.) Calculation of the annual net return associated with each forest management option-soil management group combination. Because costs and revenues occur at different points in time this requires the use of discounting procedures.

Prediction of Timber Yields.

Estimation of timber yields is a highly technical and complex matter -- often necessitating that assumptions of a judgmental nature be made. This is due to the fact timber yields are a function of many variables including tree species, stocking, site quality, and the management regime being employed. For these reasons no attempt is made in this report to prescribe "a methodology" for predicting timber yields. Instead it is recommended that in any future site specific analyses of the type described in this document, a professional forester be consulted to assist in estimating probable yields.

In the analysis of the Cherokee County study unit, as a starting point for yield prediction, the site index of each of the soil management groups was estimated. For counties which have a recent Soil Survey Report, site index figures for a variety of species, and for all soils suitable for timber growing, can be obtained from this source. In the case of Cherokee County, the required figures had to be obtained from the individual soil series descriptions for all soil series found within the county. These materials can be obtained with the assistance of appropriate personnel from the Soil Conservation Service or the Texas Agricultural Extension Service. In this study, site index figures were based on the assumption that loblolly pine would be the featured species on pine sites and sweetgum on bottomland hardwood sites.

Since the site index figures were reported for individual soils, while the relevant soil unit for purposes of this study was the soil management group, an average site index figure was calculated for each management group. As in previous instances, this was done by taking a weighted average where the weights used were the acreages of each soil within each soil management group. A sample calculation is provided in Table (14). The estimated average site indices for all the soil management groups are shown in Table (15). Note that only three site quality classes (70, 80, and 90) are represented in the pine physiographic region and two (90 and 100) in the bottomland hardwood physiographic region.

Yields for the pine management options were estimated using graphs, tables, and mathematical relationships presented in the book "Growth and Yields of Natural Stands of the Southern Pines" by Schumacher and Coile (1960). A basal area growth predictive equation developed by T. C. Nelson was used to estimate stand growth following thinnings (T. C. Nelson, 1963). This equation was as follows:

$$
\begin{aligned}
10 \times \text{Basal Area Growth per Acre (5 Yr.)} = & - 51.813058 - 0.007850(BA)^2 \\
& + 0.014660\left(BA \times \frac{10{,}000}{Age}\right) \\
& - 0.000086\left(BA^2 \times \frac{10{,}000}{Age}\right) \\
& + 0.000144(BA^2 \times Site)
\end{aligned}
$$

Where:

Age = total age of the stand at the beginning of the 5-year growth period.

Site = site index.

BA = total basal area per acre of stems 0.6 inch d.b.h. and larger at the beginning of the growth period. (T. C. Nelson, 1963).

Table (14). Determination of average site index for Soil Management Group (4).

Soil	Acreage	Site Index[1/]
Bowie fsl s.	40,500	83
Elrose fsl s.	25,800	89
Nacogdoches fsl s.	19,200	80
Ruston fsl s.	5,000	84
Total	90,500	

$$\text{Avg. SI} = \frac{40{,}500(83) + 25{,}800(89) + 19{,}200(80) + 5{,}000(84)}{90{,}500} = 84$$

[1/] Based on assumption that loblolly pine is the featured species. The site index value reflects the average height of the dominant and codominant trees at age 50.

Table (15). Estimated average site index for each Soil Management Group found within Cherokee County.

Soil Management Group	Physiographic Site Class	Average Site Index
Soil Management Group (1)	Pine	90[1/]
Soil Management Group (2)	Pine	80
Soil Management Group (3)	Pine	80
Soil Management Group (4)	Pine	80
Soil Management Group (5)	Pine	80
Soil Management Group (6)	Pine	70
Soil Management Group (7)	Pine	80
Soil Management Group (8)	Pine	80
Soil Management Group (9)	Pine	80
Soil Management Group (10)	Pine	70
Soil Management Group (11)	Pine	70
Soil Management Group (12)	Pine	80
Soil Management Group (13)	Pine	70
Soil Management Group (14)	Pine	70
Soil Management Group (15)	Bottomland Hardwood	100
Soil Management Group (16)	Bottomland Hardwood	100
Soil Management Group (17)	Bottomland Hardwood	90
Soil Management Group (18)	Bottomland Hardwood	90

[1/] All site index figures were rounded-off to nearest multiple of 10.

Among the specific assumptions made in order to arrive at the estimated pine yields were the following:

1.) For the plantation options, 908 trees are planted per acre at the time of stand establishment.

For the natural stand options, a precommercial thinning is conducted at age 5 to reduce stocking to 908 trees per acre.

2.) At age 15, basal area per acre and number of trees per acre are 125 $ft.^2$ and 760 trees on site site index 70 land. For site index 80 and 90 land the corresponding figures are 135 $ft.^2$ and 681 trees. These are judgmental values as to how many trees can be expected to survive until age 15.

3.) No natural mortality after age 15. This assumption is probably reasonable given the prescribed thinning schedules.

4.) When stands are thinned they will be thinned to a basal area equivalent to the site index value.

5.) Yields obtained by using genetically improved planting stock will be 10 percent higher than for fully stocked natural stands. This value reflects the judgment of authorities in the area of forest genetics.

6.) Yields for the short and long rotation natural stand options will be 60 and 70 percent, respectively, of those for fully stocked natural stands. These reduction factors are intended to account for the fact that most natural stands are over or understocked and consequently their volume growth is adversely affected.

Yields for the hardwood management options were more difficult to estimate because of the smaller amount of information relating to yields obtainable from managed stands. Two reference sources were used as a basis for making the predictions. The Southern Forest Experiment Station publication "Growth and Yield of Second-Growth Red Gum in Fully Stocked Stands on Alluvial soils in the

South" was used as the primary source of information about the relationships of site quality and stand age to the number of trees per acre, tree size, and stand volume (Winters and Osborn, 1935). A publication by R. L. Johnson, "Thinning Improves Growth of Stagnated Sweetgum Stands", was used to estimate the rate of basal area growth following thinning (R. L. Johnson, 1968). Among the specific assumptions that were made in order to arrive at the estimated hardwood yields were the following:

1.) The rate of natural mortality (i.e. decrease in the number of stems per acre) will correspond to that implied by the yield tables for fully stocked natural stands. However, it was also assumed that part of the volume will be recovered because of the prescribed thinning programs.

2.) When stands are thinned they will be thinned to a basal area equivalent to the site index value.

3.) Annual per acre growth in basal area following thinning will be 2.40 $ft.^2$ per acre per year on site index 90 land and 2.60 $ft.^2$ per acre per year on site index 100 land.

Yields for the custodial management option were estimated from information contained in the most recent Forest Survey report for East Texas. According to this source, the annual net growth of all growing stock occurring on commercial forest land in Cherokee County is 23.5 million cubic feet (Earles, 1976). Since there are 390,600 acres of commercial forest land in the county, this would imply an annual net growth per acre of approximately 60 $ft.^3$. When this annual net growth figure is multiplied by the stipulated cutting cycle length, 20 years, an estimate of the total volume of growth occurring over the cutting cycle is obtained. In this study it was assumed that the total net growth occurring over the cutting cycle would be harvested, and that two-thirds of the volume would be removed as sawtimber and one-third as pulpwood. The distribution of the cut between softwoods and hardwoods varied depending on the physiographic site class and was assumed to be the same as the percentage distribution of growing stock between softwoods and hardwoods on a "typical acre" in each physiographic region. What constituted a "typical acre" was estimated from the information in the Forest Survey. In Cherokee County it appears that a typical acre in the pine physiographic class has a total volume of 930 $ft.^3$ -- 66% of which is in softwoods and 34% in hardwoods. In the bottomland hardwood physiographic class the figures are 812 $ft.^3$ -- 16% of which is in softwoods and 84% in hardwoods.

For all management options, yield was initially estimated in cubic feet. The pulpwood component was then converted to cords and the sawtimber component to board feet (Doyle). These conversions were made using conversion factors obtained from the publication "Converting Factors for Southern Pine Products" (Williams and Hopkins, 1968).

The final yield figures utilized for purposes of this investigation are shown in Table (16).

Valuation of Timber Yields.

In order to convert the predicted timber yields in Table (16) into their monetary equivalents, current stumpage prices for softwood pulpwood, softwood sawtimber, hardwood pulpwood, and hardwood sawtimber had to be determined. Since Texas presently has no price reporting service for forest products, figures published in the "Louisiana Forest Products Quarterly Market Report" were utilized. The figures collected were those given for reporting regions (1) and (3) -- the two regions which border against Texas. To help insure that the effect of any market irregularities would be minimized, average

Table (16). Predicted timber yields that will result from applying the various management options on different quality sites.

Forest Management Options	Site Index 70 Pulpwood (cords)	Site Index 70 Sawtimber (MBF)	Site Index 80 Pulpwood (cords)	Site Index 80 Sawtimber (MBF)	Site Index 90 Pulpwood (cords)	Site Index 90 Sawtimber (MBF)	Site Index 100 Pulpwood (cords)	Site Index 100 Sawtimber (MBF)
Short Rotation Pine Plantation								
Commercial thin at age 15	6.93	--	7.48	.11	7.41	.13	--	--
Harvest cut at age 25	8.38	.73	8.03	1.43	11.62	1.99	--	--
Medium Rotation Pine Plantation								
Commercial thin at age 15	6.93	--	7.48	.11	7.41	.13	--	--
Commercial thin at age 22	6.57	.37	6.93	.76	9.04	1.03	--	--
Commercial thin at age 29	2.87	.66	2.71	1.16	4.03	1.66	--	--
Harvest cut at age 35	4.82	3.17	4.42	5.30	7.28	8.04	--	--
Long Rotation Pine Plantation								
Commercial thin at age 20	12.79	.27	13.75	.57	14.95	.78	--	--
Commercial thin at age 35	6.36	1.74	6.16	2.61	8.34	3.36	--	--
Commercial thin at age 50	1.30	1.69	1.25	3.06	1.86	4.59	--	--
Harvest cut at age 60	1.65	5.04	1.51	9.19	2.09	13.12	--	--
Short Rotation Pine Natural Stand								
Commercial thin at age 15	3.78	--	4.03	.05	4.04	.07	--	--
Commercial thin at age 25	4.57	.40	4.38	.78	6.34	1.09	--	--
Harvest cut at age 35	3.73	1.92	3.53	3.37	5.77	4.91	--	--
Long Rotation Pine Natural Stand								
Commercial thin at age 20	8.95	.19	9.62	.40	10.46	.55	--	--
Commercial thin at age 40	4.90	1.60	4.43	2.62	6.08	3.80	--	--
Commercial thin at age 60	.75	1.64	.70	2.87	1.05	4.56	--	--
Harvest cut at age 70	.97	4.10	.84	7.33	1.13	11.28	--	--

Table (16). Continued.

Forest Management Options	Site Index 70 Pulpwood (cords)	Site Index 70 Sawtimber (MBF)	Site Index 80 Pulpwood (cords)	Site Index 80 Sawtimber (MBF)	Site Index 90 Pulpwood (cords)	Site Index 90 Sawtimber (MBF)	Site Index 100 Pulpwood (cords)	Site Index 100 Sawtimber (MBF)
Short Rotation Hardwood Natural Stand								
Commercial thin at age 20	--	--	--	--	2.92	--	8.55	--
Commercial thin at age 35	--	--	--	--	13.12	.20	15.76	.53
Harvest cut at age 50	--	--	--	--	42.22	5.04	40.68	3.03
Long Rotation Hardwood Natural Stand								
Commercial thin at age 30	--	--	--	--	13.71	.06	17.30	.26
Commercial thin at age 50	--	--	--	--	23.74	2.83	21.32	4.21
Harvest cut at age 80	--	--	--	--	24.14	17.61	18.49	24.32
Custodial Management								
Pine physiographic site class								
Softwood component	4.82	1.60	4.82	1.60	4.82	1.60	--	--
Hardwood component	2.41	.80	2.41	.80	2.41	.80	--	--
Bottomland Hardwood physiographic class								
Softwood component	--	--	--	--	1.20	.40	1.20	.40
Hardwood component	--	--	--	--	6.02	2.00	6.02	2.00
Undisturbed Forest[1/]	--	--	--	--	--	--	--	--

[1/] By definition the Undisturbed Forest option does not provide any timber yield.

prices for the 5-year period from 1973 to 1977 were computed. The resultant market price estimates are shown in Table (17). When these figures are multiplied by the yield figures presented earlier in Table (16), an estimate of the gross revenue to be obtained by applying a particular management option on a particular quality site is obtained.

Estimation of Management Costs.

Information pertaining to the costs of utilizing different forest practices was obtained from essentially two sources: (1) personal communication with industrial foresters and Texas Forest Service personnel, and (2) the results of the most recent forestry cost survey published by Forest Farmer magazine (Moak, Kucera, and Watson, 1977). The specific cost assumptions that have been used in this investigation are set forth in Table (18).

Estimation of Annual Net Returns.

At this juncture the annual net returns that can be expected to result from applying a particular forest management option on a particular soil management group (i.e. quality of site) can be estimated. Each management option-soil management group combination can be viewed as a stream of costs and revenues extending into the future. Using appropriate discounting procedures the net present worth of either a single rotation or repeated rotations can then be ascertained. Finally, the calculated net present worth can be annualized by use of the appropriate "equal-payment-series capital-recovery factor".

Discounting is unavoidable in the evaluation of alternative timber management opportunities such as those envisioned in this study. Since the costs and revenues associated with each alternative are widely separated in time, some method is needed in order to recognize both the potential returns realizable from non-forestry investments and also the changing value of the dollar over time.

Table (17). Estimated market prices for selected timber products. (Source: Louisiana Forest Products Quarterly Market Reports for 1973 - 1977.)

Type of Product	Estimated Current Market Price1/
Pine sawtimber	$88.08/Mbf2/
Hardwood sawtimber	30.58/Mbf
Pine pulpwood	6.04/cord
Hardwood pulpwood	2.41/cord

1/ The wisdom of using a 5-year average price can be questioned. Stumpage prices in East Texas have shown a sharp rising trend over the last few years and there are no foreseeable reasons to expect them to go down. If current market prices were utilized, values of $120.00/Mbf for pine sawtimber and $7.10/cord for pine pulpwood would be appropriate. (Source: Personal communication with Ed Barron, Head, Forest Management Department, Texas Forest Service.)

2/ Sawtimber prices are expressed in terms of Mbf (Doyle).

Table (18). Assumed forest management costs. (Source: Forest Farmer magazine and personal communications.)

Management Practice/Cost Item	Estimated Cost/Acre1/
Mechanical site preparation	
Shearing	$50.00
Chopping2/	33.00
Machine planting	
Initial rotation	27.50
Subsequent rotations3/	20.00
Seedlings4/	
Loblolly (improved)	11.80
Loblolly (unimproved)	9.08
Prescribed burn	1.50
Precommercial thinning	19.00
Weeding and release	30.00
Annual management expense5/	
Plantation and natural stand options	3.25
Custodial management option	2.25
Undisturbed forest option	1.50

1/ The cited figures are primarily indicative of the costs experienced by forest industry. In the case of the non-industrial private woodland owner, the unit costs would typically be higher. This is due to the fact that within this latter ownership class, forestry operations are normally conducted on a much smaller scale.

2/ It has been assumed that chopping will be the method of site preparation in subsequent rotations.

3/ It has been assumed that planting costs will be less in subsequent rotations.

4/ These cost figures are based on the assumption that improved seedlings cost $13/M unimproved seedlings $10/M and 908 trees are planted per acre.

5/ Reflects costs for property taxes, professional services, protection, boundary maintenance, etc. These decrease as management intensity decreases.

The required discounting calculations can be handled in either of two ways. One possibility is to express all future costs and revenues in terms of expected future dollars. In this instance present values are calculated be in effect discounting the future values twice -- once using the decision-maker's real alternative rate, and once using the expected average rate of inflation. The other possibility is to leave all future costs and revenues expressed in terms of present dollars. In this instance, the desired present values are calculated by discounting only once using the decision-maker's real alternative rate. In this study the second of these two alternative approaches has been utilized.

Discounting formulas for a variety of value streams can be found in almost any economics text; in this instance they were taken from the book Fundamentals of Forestry Economics (Duerr, 1960). The specific formulas employed in the study were those described below.

1.) The formula for the discounted present value of an infinite annual series of equal values. This formula states:

$$V_o = \frac{r}{i}$$

Where:

V_o = present value of the infinite annual series of equal values.

r = annually recurring value (i.e. cost or revenue).

i = decision-maker's real alternative rate of interest.

This formula was used to calculate the present value of the undisturbed forest option. The value stream for this option consists of only the annual management expenses. Assuming that a piece of land is retained in this option, this value stream would be infinite in length.

2.) The formula for the discounted present value of a single future value. This formula states:

$$V_o = \frac{V_n}{(1 + i)^n}$$

Where:

V_o = present value of the single future value.

V_n = the single future value (i.e. cost or revenue).

i = decision-maker's real alternative rate of interest.

n = number of years over which the single future value must be discounted.

This formula was applied to all options except for the undisturbed forest. It was used to calculate the present values of those costs or revenues that do not occur -- over the course of a rotation or cutting cycle -- either annually or at some other regular periodic interval. These costs and revenues would be represented by such things as irregular prescribed burns and commercial thinnings.

3.) The formula for the discounted present value of a terminable annual series of equal values. This formula states:

$$V_o = \frac{r[(1 + i)^n - 1]}{i(1 + i)^n}$$

Where:

V_o = discounted present value of the terminable annual stream of equal values.

r = the annually recurring value (i.e. cost or revenue).

i = decision-maker's real alternative rate of interest.

n = number of years in the terminable annual series.

This formula was applied to all options except for the undisturbed forest. It was used to calculate the present value of the stream of equal annual management expenses that are incurred over the course of the rotation or cutting cycle.

4.) The formula for net present worth. This formula states:

$$NPW = PVI - PVC$$

Where:

NPW = net present worth.

PVI = present value of all incomes.

PVC = present value of all costs.

This formula was applied to all options except for the undisturbed forest. It was used to compute net present worth of a single rotation or cutting cycle. Once this figure had been obtained, the net present worth of an infinite series of such rotations or cutting cycles was calculated from the following relationship:

$$NPW_I = NPW_S \left[1 + \frac{1}{(1 + i)^n - 1} \right]$$

Where:

NPW_I = net present worth of an infinite series of rotations or cutting cycles.

NPW_S = net present worth of a single rotation or cutting cycle.

i = decision-maker's real alternative rate of interest.

n = number of years in the rotation or cutting cycle.

NPW was calculated for perpetual rotations or cutting cycles in order to insure that the returns obtained from the different management options were based on equal time periods. This precludes the bias that would be inherent in trying to make a direct comparison between the returns obtained from single rotations of substantially different lengths.

The discount rate assumed for purposes of this study was 5 percent. This appears to be a reasonable rate when one recognizes that current market interest rates, which have been running on the order of 8 or so percent, probably include an allowance of at least 3 percent for the effect of inflation. From another perspective, it can be noted that long-term certificates of deposit are now available which offer interest rates on the order of 8 percent. If one anticipates that inflation will be on the order of 3 percent in the years ahead, then once again the implied real rate of interest is on the order of 5 percent.

An example of how the preceding discounting formulas can be used to estimate the annual net return that will result from applying a particular forest management option on a certain quality of site is provided in Table (19). This particular illustration is for the short rotation pine natural stand option on site index 80 land, but all the other possibilities would be handled in the same manner. The end result of going through this computational process for all the "management option-site quality" combinations would be the figures presented in Table (20).

Final Linear Programming Model

The specific Linear Programming model used to study the economic impacts of imposing silvicultural nonpoint controls in Cherokee County can now be set forth. The model is shown in equation form below and in matrix form in Figure (3).

Maximize:

$$z = \sum_{i=1}^{18} \sum_{j=1}^{9} c_{ij} x_{ij}$$

Subject To:

$$\sum_{j=1}^{9} x_{ij} = bi \qquad \text{for } i = 1, 2, \ldots, 18$$

Table (19): Illustrating determination of annual net return for short rotation pine natural stand option on site index 80 land. (5% discount rate)

Year	Management Practice	Revenues ($/Ac.)	Costs ($/Ac.)	PV Revenues ($/Ac.)	PV Costs ($/Ac.)
0	Liquidate old stand	152.58[1/]		152.58	
1			3.25		3.10
2			3.25		2.95
3			3.25		2.81
4			3.25		2.67
5	Precommercial thin		22.25		17.43
6			3.25		2.43
7			3.25		2.31
8			3.25		2.20
9			3.25		2.10
10			3.25		2.00
11			3.25		1.90
12			3.25		1.81
13			3.25		1.72
14			3.25		1.64
15	Commercial thin & burn	22.92	4.75	14.39	2.28
16			3.25		1.49
17			3.25		1.42
18			3.25		1.35
19			3.25		1.29
20			3.25		1.22
21			3.25		1.17
22			3.25		1.11
23			3.25		1.06
24			3.25		1.01
25	Commercial thin & burn	95.16	4.75	28.10	1.40
26			3.25		.91
27			3.25		.87
28			3.25		.83
29			3.25		.79
30			3.25		.75
31			3.25		.72
32			3.25		.68
33			3.25		.65
34			3.25		.62
35	Harvest	318.15	3.25	57.68	.59
Totals				252.75	69.28

NPW (1st rotation) = 252.75 - 69.28 = 183.47
NPW (2nd rotation) = 252.75 - (152.58 + 69.28) = 30.89

$$\text{NPW (infinite rotations)} = 183.47 + \left[\frac{30.89}{(1.05)^{35}-1} \right] = 190.31$$

Table (19): Continued

Annual Net Return = 190.31 (.05)[2/] = \$9.51/Ac./Yr

[1/] For each plantation and natural stand option a value has been assigned to the beginning of the first rotation to reflect the income that would be received from liquidation of the existing stand. This income figure is based on estimated average stand conditions and current market prices. Such values could be excluded from the analysis and the effect would be to reduce the annual net return.

[2/] The "equal-payment-series capital-recovery factor" is:

$$\left[\frac{i(1 + i)^n}{(1 + i)^n - 1}\right]$$

As n approaches infinity this factor will approach the value of i --- .05 in this example.

Table (20). Annualized net present worth for each management option site index combination.

Forest Management Option	Site Index 70	Site Index 80	Site Index 90	Site Index 100
	($/Ac./Yr.)			
Short rotation pine plantation	2.45	4.14	5.67	--
Medium rotation pine plantation	6.50	10.33	14.77	--
Long rotation pine plantation	5.63	8.53	11.94	--
Short rotation pine natural stand	7.23	9.51	11.80	--
Long rotation pine natural stand	7.14	9.00	11.21	--
Short rotation hardwood nat. stand	--	--	1.31	1.99
Long rotation hardwood nat. stand	--	--	1.12	1.65
Custodial management				
Pine site	3.81	3.81	3.81	--
Bottomland Hardwood site	--	--	1.33	1.33
Undisturbed forest	-1.50	-1.50	-1.50	-1.50

Obj. Fn. and Constraints	Type of Constraint	SPP 1	. . . . .	SPP 14	MPP 1	. . . . .	MPP 14	LPP 1	. . . . .	LPP 14	SPM 1	. . . . .	SPM 14
		Activities (i.e. management option-soil group combinations)											
OF	N	5.67		2.45	14.77		6.50	11.94		5.63	11.80		7.23
S.G.1	E	1			1			1			1		
S.G.2	E												
S.G.3	E												
.													
.													
.													
S.G.17	E												
S.G.18	E												
SL	N, L	.0245	. . . .	.3029	.0226	. . . .	.2800	.0208	. . . .	.2570	.0219	. . . .	.2708

Obj. Fn. and Constraints	Type of Constraint	LPM 1	. . . . .	LPM 14	SHM 15	. . .	SHM 18	LHM 15	. . .	LHM 18	CM 1	. . . . . .	CM 18	UF 1	. . . . .	UF 18	Right Hand Side
		Activities (i.e. management option-soil group combinations)															
OF	N	11.21		7.14	1.99		1.13	1.65		1.12	3.81		1.33	-1.50		-1.50	
S.G.1	E	1									1			1			624
S.G.2	E																21364
S.G.3	E																9148
.																	.
.																	.
.																	.
S.G.17	E																2721
S.G.18	E						1			1			1			1	16423
SL	N, L	.0200	. . . .	.2479	.0191	. . .	.0284	.0173	. . .	.0257	.0186	. . . . . .	.0268	.0026	. . . .	.0038	

Figure (3). Matrix representation of Linear Programming model used in analysis of Cherokee County.

$$\sum_{i=1}^{18} \sum_{j=1}^{9} a_{ij}x_{ij} \quad (=, \leq) \ L$$

and:

$$x_{ij} \geq 0 \quad \text{for } i = 1, 2, \ldots, 18$$
$$j = 1, 2, \ldots, 9$$

Where:

z = annualized net present income received by all forest landowners from forest management activities conducted within Cherokee County.

x_{ij} = number of acres within soil management group i which are managed using forest management option j.

c_{ij} = annual net present income received from managing one acre within soil management group i under forest management option j. (Note: these values are obtained from Table 20.)

bi = number of acres of commercial forest land in soil management group i within Cherokee County. (Note: i = 1, 2, . . ., 18 since there are 18 soil management groups in the study area. The specific acreages for each group are obtained from Table 7.)

a_{ij} = amount of soil loss (i.e. sheet and rill erosion), in tons per acre per year, that results from managing one acre within soil management group i under forest management option j. (Note: these values are obtained from Table 13.)

L = amount of soil loss (i.e. sheet and rill erosion), in tons per year, resulting from forestry activities conducted on all commercial forest lands in Cherokee County. (Note: the model is either allowed to determine this value or it is imposed as a constraint.)

To facilitate interpretation of the matrix representation of the LP model (i.e. Figure 3), the following notational definitions are provided:

SPP = Short rotation pine plantation

MPP = Medium rotation pine plantation

LPP = Long rotation pine plantation

SPN = Short rotation pine natural stand

LPN = Long rotation pine natural stand

SHN = Short rotation hardwood natural stand

LHN = Long rotation hardwood natural stand

CM = Custodial management

UF = Undisturbed forest

SMG = Soil management group

OF = Objective function

SL = Soil loss constraint

N = row that is nonconstrained

E = strict equality constraint

L = less than or equal to constraint

PRESENTATION OF STUDY FINDINGS

As noted in the introductory chapter, an objective of this investigation was to evaluate the economic impacts of applying several alternative methods for reducing the soil loss resulting from silvicultural activities. The purpose of this chapter is to present such evaluative results for the Cherokee County study unit. All evaluations were made using the Linear Programming model described in the previous chapter. The model itself was solved using the IBM MPS-360 computer routine and the data processing facilities at Texas A&M University. Detailed information on how to use this computer package is provided in the report "A User's Guide to Linear Programming and the IBM MPS-360 Computer Routine" (Freeman and Lard, 1970).

The content of the chapter is organized around the 4 control alternatives considered in this study. These were: (1) an aggregate (i.e. countywide) soil loss limit; (2) a per acre soil loss limit; (3) a tax on excess soil loss; and (4) a subsidy for reduced soil loss. In each instance, the proposed controls are evaluated in terms of their impacts on: (1) total annualized net income resulting from forest management activities; (2) total annual soil loss resulting from forest management activities; and (3) total annual timber yields. In the case of the tax and subsidy alternatives, the impacts of the controls on governmental costs and revenues are also considered.

Aggregate Soil Loss Limit

Under this policy option, total soil loss resulting from silvicultural activities must be held at or below some specified limit. As this limit becomes more restrictive, landowners are forced to shift to those forest management options that result in less average annual soil loss. The question is -- what are the economic implications of forcing this type of behavior?

The estimated impacts of imposing an aggregate soil loss limit on silvicultural activities in Cherokee County are summarized in Table (21). With soil loss unconstrained, the profit-maximizing mix of management options will provide forest landowners in the county with an annual net income in excess of $3 million. The total amount of soil loss associated with this profit-maximizing mix of activities is 143,718 tons. Given that there are 390,600 acres of commercial forest land in the county, the average soil loss rate associated with this optimum solution is only .37 tons/acre/year.

The other aggregate soil loss values shown in Table (21) were entered into the LP model as progressively more stringent constraints. They correspond to average annual erosion rates of .3, .2, .1, .05, and .01 tons/acre/year. If the successive reductions in soil loss are divided into the successive reductions in income required to achieve them, it is found that the ratios get progressively larger. This implies that as the soil loss limit is made more binding, each incremental reduction in soil loss can only be achieved at an increasing cost to forest landowners. This relationship is evident from the "income-soil loss" trade-off function shown in Figure (4). As the shape of the curve implies, any reduction of soil loss from the level corresponding to the optimum solution will require a sacrifice in income -- but the rate at which landowner income will be reduced becomes progressively greater. To illustrate, in decreasing soil loss from 143,718 to 117,180 tons/year (i.e. a reduction of 26,532 tons/year), income to forest landowners is decreased by $213,395 per year (i.e. $3,135,311 minus $2,921,916) -- this implies that an annual opportunity cost of $8.04 (i.e. $213,395/yr. divided by 26,532 tons/yr.) is incurred for each ton of reduced soil loss. By comparison, in decreasing soil loss from 39,060 to 19,530 tons/year, the equivalent opportunity cost figure is $75.27 per ton.

Table (21): Economic impacts of imposing an aggregate limit on soil loss from silvicultural activities in Cherokee County.

Level of Agg. Soil Loss Limit	Ann. Net Income from Forest Mgmt.	Ann. Timber Yield[1/]	
		Pine	Hardwood
(Tons/Yr.)	($/Yr.)	(Ft^3/Yr.)	(Ft^3/Yr.)
143,718[2/]	3,135,311	40,826,860	4,897,030
117,180	2,921,916	38,268,644	4,897,030
78,120	2,470,862	34,840,718	4,897,030
39,060	1,593,173	22,927,487	4,897,030
19,530	123,203	7,388,281	4,733,771
3,906	----------------Infeasible Solution--------------------		

1/ Estimates of the average annual timber yield that would result from applying a particular forest management option on a particular quality site were developed for all management option-site quality combinations. This was done by aggregating -- for each possible combination -- the yields obtained from all commercial thinnings plus the final harvest cut. This total yield was then divided by the number of years in the rotation or cutting cycle to give the desired average annual timber yield figure. With these figures available for each management option-site quality combination, the effects of the soil loss limit on timber yield can be estimated from knowledge of how the limit causes the optimum mix of managment activities to change. The basic data on average annual timber yields are provided in Appendix B.

2/ Amount of soil loss associated with optimum solution when soil loss is not treated as a constraint in the model.

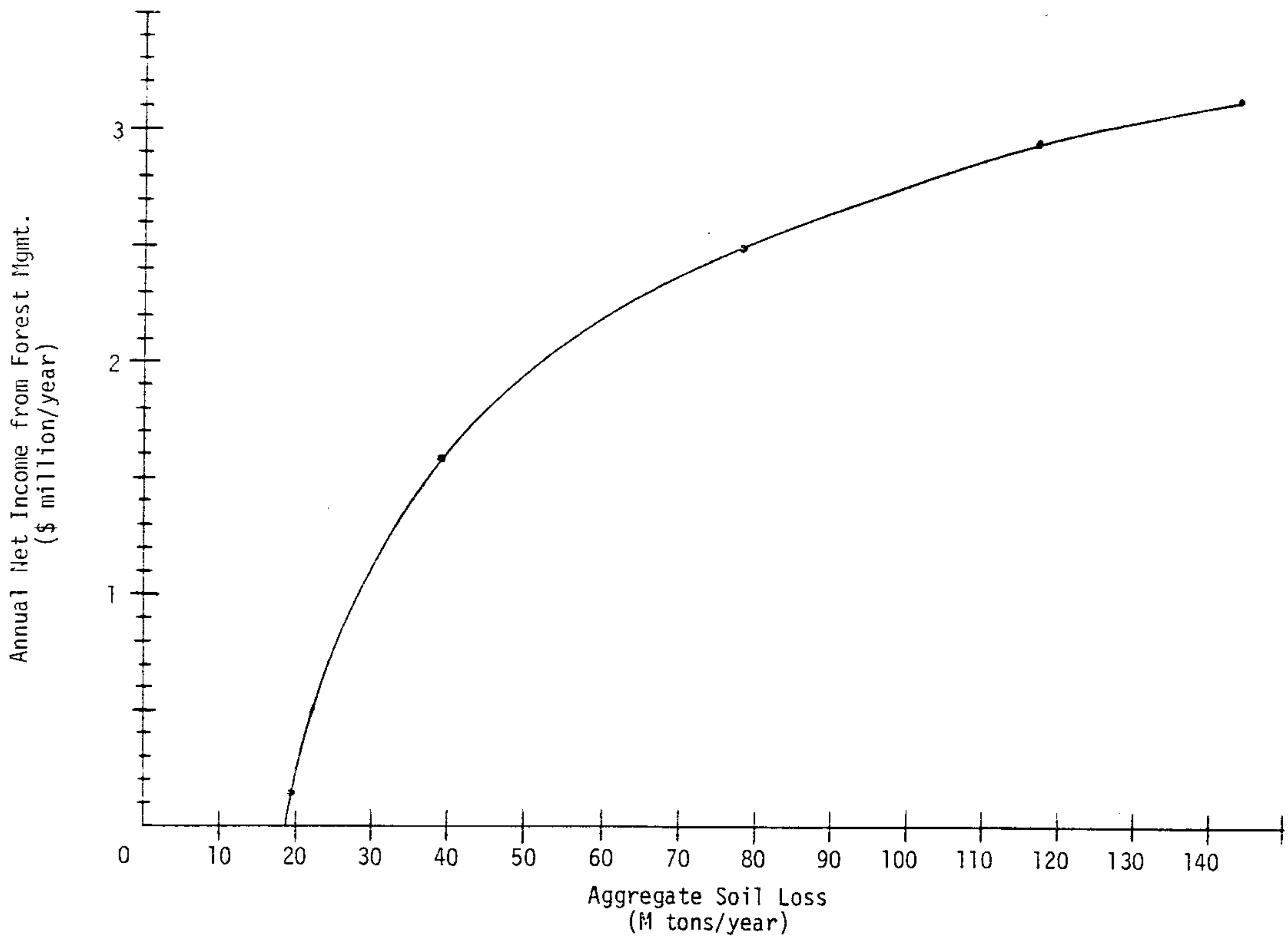

Figure (4). Income-soil loss tradeoff function associated with imposing an aggregate soil loss limit.

The reduction in landowner income that accompanies a reduction in aggregate soil loss is a consequence of the fact that the most profitable management options also tend to be those that result in more soil loss. For the most part these are the options with short to medium rotation lengths. Such alternatives are typically favored by discounting calculations but from a soil loss standpoint they also imply more frequent disturbance of the site. In the initial solution of the LP model, when soil loss was left unconstrained, the medium rotation pine plantation and short rotation pine natural stand options predominated in the optimal solution. As soil loss constraints became increasingly stringent, these options gave way to others. Initially the trend was into long rotation pine natural stand but ultimately more and more soil management groups were forced into either custodial management or undisturbed forest. The rate at which a particular soil management group shifted into undisturbed forest was clearly related to the potential erodibility of the soil itself. In this study, soil management group 13 was the most highly erodible and it was also the first to move into undisturbed forest.

The fact that the more intensive forest management options tend to be those resulting in more soil loss also explains why annual timber yields decline as soil loss restrictions become more binding. It would be possible to construct a "timber yield-soil loss" trade-off function similar to the one presented previously for income. If this were done, essentially the same pattern would be revealed -- successive incremental reductions in soil loss require progressively greater reductions in timber yield. To illustrate, as soil loss is reduced from 143,718 to 117,180 tons/year, the average reduction in timber yield is 96.4 $ft.^3$ per ton. However, as soil loss is reduced from 39,060 to 19,530 tons/year, the average reduction in timber yield is 804.0 $ft.^3$ per ton.

Per Acre Soil Loss Limit

Under this policy option, no forest management alternative can be applied to a particular soil management group if it will result in an average annual per acre soil loss, over the course of a rotation or cutting cycle, that exceeds some specified limit. As this limit becomes more restrictive, landowners are once again forced to shift to those management options that will result in less soil loss. The primary difference between this policy and the aggregate soil loss restriction is that the present policy leaves landowners less flexibility to determine which management options they should use in order to maximize annual net income. Under the previous system it was possible that a management alternative which resulted in substantial soil losses might still be utilized if its income producing potential was sufficiently great to offset the effect of having to employ less intensive options on other areas. All that was required was that all options -- in combination -- were within the overall constraint. In this instance each individual management alternative must satisfy the constraint.

The estimated impacts of imposing a per acre soil loss limit on silvicultural activities in Cherokee County are summarized in Table (22). Again, the first entry in the table corresponds to the optimum solution to the LP model when soil loss is left unconstrained. The other table entries were obtained by making repetitive computer runs in such a way that in each repetition any activities that would result in a soil loss in excess of the specified per acre limit were eliminated from the model. The various computer runs that were made stipulated per acre soil loss limits of .8, .6, .4, .3, .2, and .1114 tons/acre.

The data for the per acre soil loss limit correspond quite closely with that obtained for the aggregate soil loss limit. Looking at the "income-soil loss" tradeoff function in Figure (5), one can see that the same pattern is evident.

Table (22): Economic impacts of imposing a per acre limit on soil loss from silvicultural activities in Cherokee County.

Per Acre Limit	Level of Agg. Soil Loss	Ann. Net Income from Forest Mgmt.	Ann. Timber Yield Pine	Ann. Timber Yield Hardwood
(Tons/Ac./Yr.)	(Tons/Yr.)	($/Yr.)	(Ft^3/Yr.)	(Ft^3/Yr.)
None	143,718	3,135,311	40,826,860	4,897,030
.8	128,558	2,773,523	39,557,423	4,897,030
.6	56,148	2,211,799	33,201,263	4,897,030
.4	56,022	2,202,313	33,061,564	4,897,030
.3	55,529	2,194,587	32,974,264	4,897,030
.2	27,810	858,521	15,901,703	4,897,030
.1114	26,859	715,451	13,001,426	4,897,030

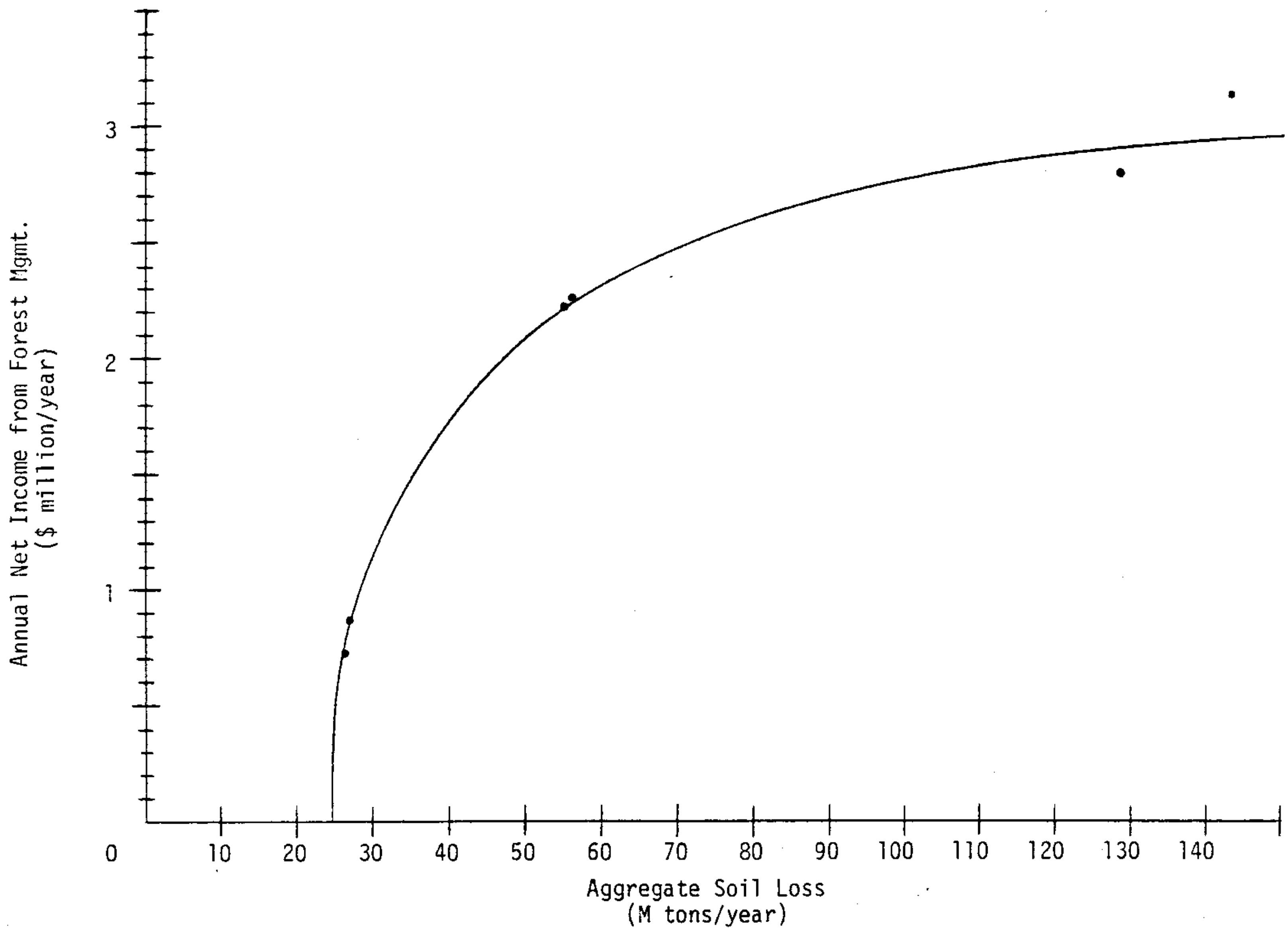

Figure (5). Income-soil loss tradeoff function associated with imposing a per acre soil loss limit.

As per acre soil loss restrictions are made increasingly stringent, each successive decrease in soil loss necessitates a larger and larger decrease in the net income received by forest landowners. The exact rate of tradeoff between income and soil loss can be geometrically determined, at any point on the tradeoff function, by simply constructing a tangent to the curve and measuring the slope of the tangent. The slope of the tangent will be equal to the rate of tradeoff at the point of tangency. This procedure is illustrated in Figure (6). It can be applied to any of the tradeoff functions developed in this study.

For comparative purposes, we can evaluate the "efficiency" of each control option using the formula below. The option which maximizes the value of this ratio would be the "most efficient".

$$\text{Efficiency} = \frac{\text{Agg. Income to Forest Landowners}}{\text{Agg. Soil Loss}}$$

Comparing the aggregate and per acre soil loss limits on the basis of this efficiency criterion indicates that there is little difference between the two. Within the range of aggregate soil loss from 30,000 and 100,000 tons/year, the per acre soil loss limit appears to be slightly preferable. Above or below this range, the aggregate soil loss limit is better. This can be seen quite clearly if the two tradeoff functions are either superimposed on one another or graphed on the same set of axis.

The effect of the per acre limit, like that of the aggregate limit, is to force landowners to switch from use of the short and medium length natural stand and plantation options to less intensive forms of management. The inevitable result of this is the decline in timber yield which is reflected in Table (22). As was true for the aggregate soil loss limit, timber yields decrease by progressively larger amounts as the per acre soil loss restriction becomes more binding.

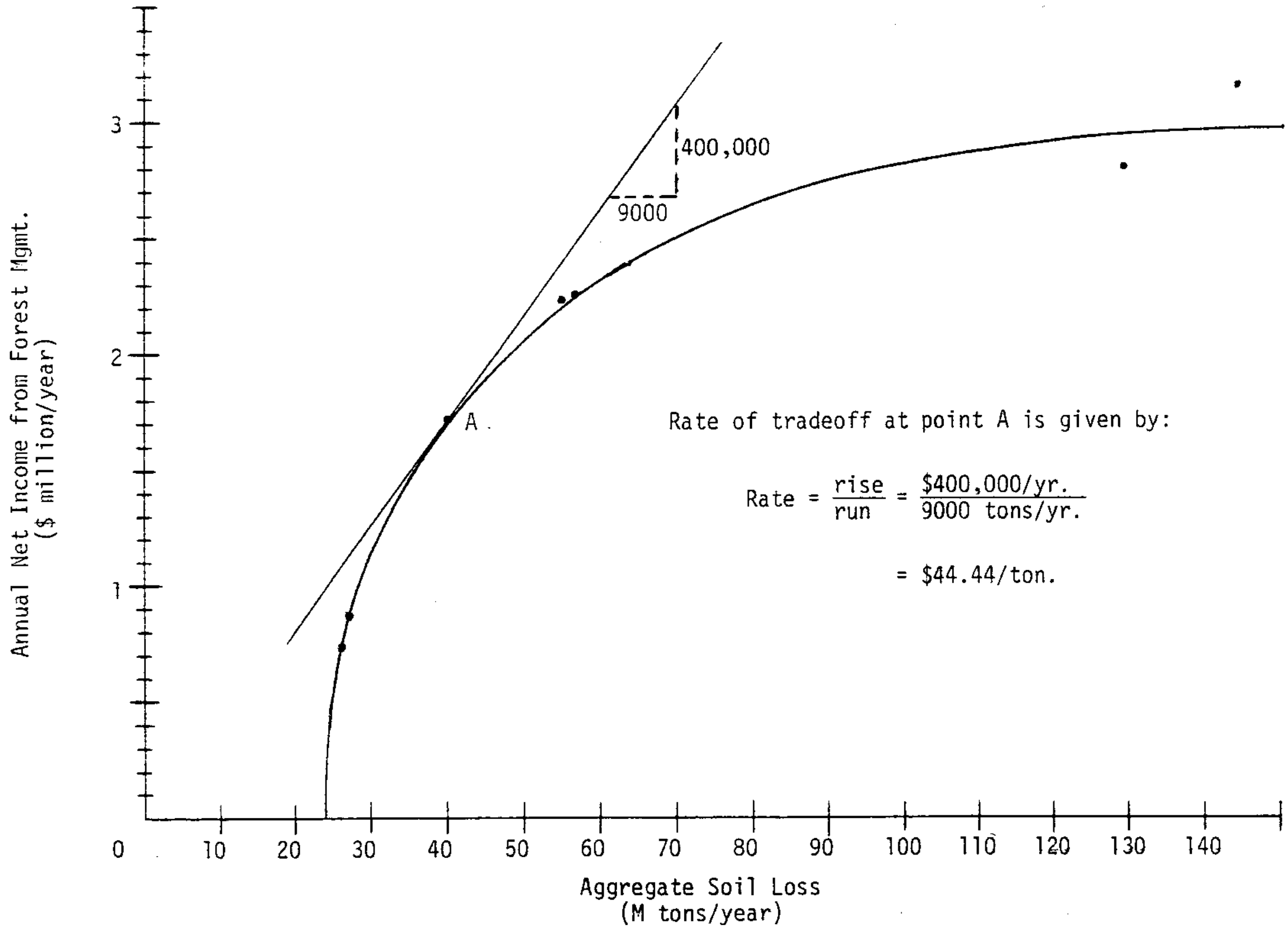

Figure (6). Procedure for estimating rate of tradeoff between income and soil loss.

Tax on Excess Soil Loss

In spite of the fact that they may be unpopular, taxes constitute a distinct policy alternative for attempting to reduce soil loss. A tax which is directly related to the level of soil loss would provide a definite economic incentive for landowners to reduce such losses. This would occur because those management options resulting in higher amounts of soil loss would be made financially less attractive relative to those resulting in only small or moderate losses.

In order to estimate what the impacts would be of imposing a tax on soil loss from silvicultural activities in Cherokee County, a basis for the imposition of the tax first had to be established. This was done by employing the following reasoning. For each soil management group, that timber management alternative which would result in the lowest annual soil loss per acre was determined. Without exception this was the undisturbed forest management option. The amount of annual soil loss for this option was then subtracted from the amount of annual soil loss associated with all the other management alternatives which could be employed on the soil management group in question. The differences obtained through this subtraction process indicate the extent to which actual soil losses, for each of the various forest management options, exceed the minimum soil loss possible for the particular soil management group in question. It was on the basis of these differences that the amount of tax was determined.

Because the average annual per acre soil loss is so small for the various management alternatives, and because the degree of variation in soil loss is rather small from one option to another, it was found that tax rates had to be increased to quite dramatic levels before there was any appreciable realignment of management alternatives and corresponding reduction in soil loss. Repetitive computer runs were made using annualized net present worth figures that were adjusted to reflect the imposition of a tax on excess soil loss at rates of

$2, $4, $6, $8, $10, $20, $40, $60, and $80 per ton.[1/] The observed tradeoffs between soil loss, annual net income to forest landowners, aggregate timber yield, and government tax receipts were as shown in Table (23).

As the table indicates, over the range of alternative tax rates from $2 to $10/ton there is only a slight reduction in aggregate soil losses and timber yields. About the only significant effect is an increasing transfer of wealth from forest landowners to the government. Landowners maintain the use of the same forest management alternatives, but the alternatives are no longer as profitable due to the imposition of the tax. As the tax rate is increased above $10/ton there is a substantial decrease in soil loss. This is largely attributable to the movement of soil management group 13, the largest group within the county, into an undisturbed forest situation. As the tax rate is increased to even higher levels, an increasing number of soil management groups move into undisturbed forest. This is marked by continued decreases in soil loss and a drastic decline in pine timber yields.

From the standpoint of the forest landowner, the soil loss tax appears to be the least attractive of the three control options considered up to this point -- particularly at very low levels of soil loss. A comparison of tables (21), (22), and (23) indicates that in this lower range, the aggregate income received by these landowners is less, for any given level of soil loss, under the tax option. There is some question, however, about whether this is an appropriate basis for comparing the options. From a social standpoint, income received by government may be considered as having the same value as income received by private forest landowners. If one accepts this viewpoint, then government tax receipts should be added to landowner income in determining the nature of the

[1/] The tax and revised annual net income figures used to perform this analysis are provided in Appendix C.

Table (23): Economic impacts of imposing a tax on excess soil loss from silvicultural activities in Cherokee County.

Tax Rate	Annual Soil Loss	Ann. Net Income from Forest Mgmt.	Government Tax Receipts	Agg. Timber Yield Pine	Agg. Timber Yield Hardwood
($/Ton)	(Tons/Yr.)	($/Yr.)	($/Yr.)	(Ft^3/Yr.)	Ft^3/Yr.)
0	143,718	3,135,311	0	40,826,860	4,897,030
2	135,297	2,888,625	237,163	35,489,515	4,897,030
4	135,297	2,652,819	472,971	35,489,515	4,897,030
6	134,699	2,417,022	705,864	35,311,858	4,897,030
8	134,699	2,180,595	942,843	35,311,858	4,897,030
10	134,422	1,942,185	1,174,613	35,129,020	4,897,030
20	55,199	1,443,934	761,821	33,004,697	4,897,030
40	54,580	683,278	1,505,180	32,768,696	4,729,710
60	27,468	226,390	628,351	19,998,862	4,897,030
80	25,746	11,614	835,926	19,998,862	4,773,770

income-soil loss tradeoffs for the tax option. This has been done in Figure (7). A comparison of this "societal" tradeoff function with those for the other policy options indicates that when viewed from this new perspective the tax alternative is indeed preferable at virtually any level of soil loss below that for the unconstrained optimum solution.

Subsidy for Reduced Soil Loss

The last potential soil loss control option to be explicitly evaluated in this study consisted of a subsidy (i.e. government payment) to encourage forest landowners to reduce soil loss. As envisioned, this option is essentially just the opposite of the tax system. Instead of penalizing landowners for employing those management options that result in a relatively high soil loss, you reward them for using those management options that result in only modest soil losses. Ideally, the level of the subsidy should be directly related to the amount by which soil loss is reduced.

In order to approximate what the impacts would be of offering subsidy payments to forest landowners in Cherokee County, a basis for determining the appropriate amount of subsidy had to be established. This was done by employing the following reasoning. For each soil management group, that timber management alternative which would result in the highest annual soil loss per acre was determined. Without exception this was the short rotation pine plantation option. The amount of annual soil loss associated with all the other management alternatives that might be applied on a particular soil management group were then deducted from this maximum amount of soil loss. The differences obtained through this subtraction process indicate, for each soil management group considered, the reduction in soil loss that occurs as a consequence of using some option other than the one that results in the

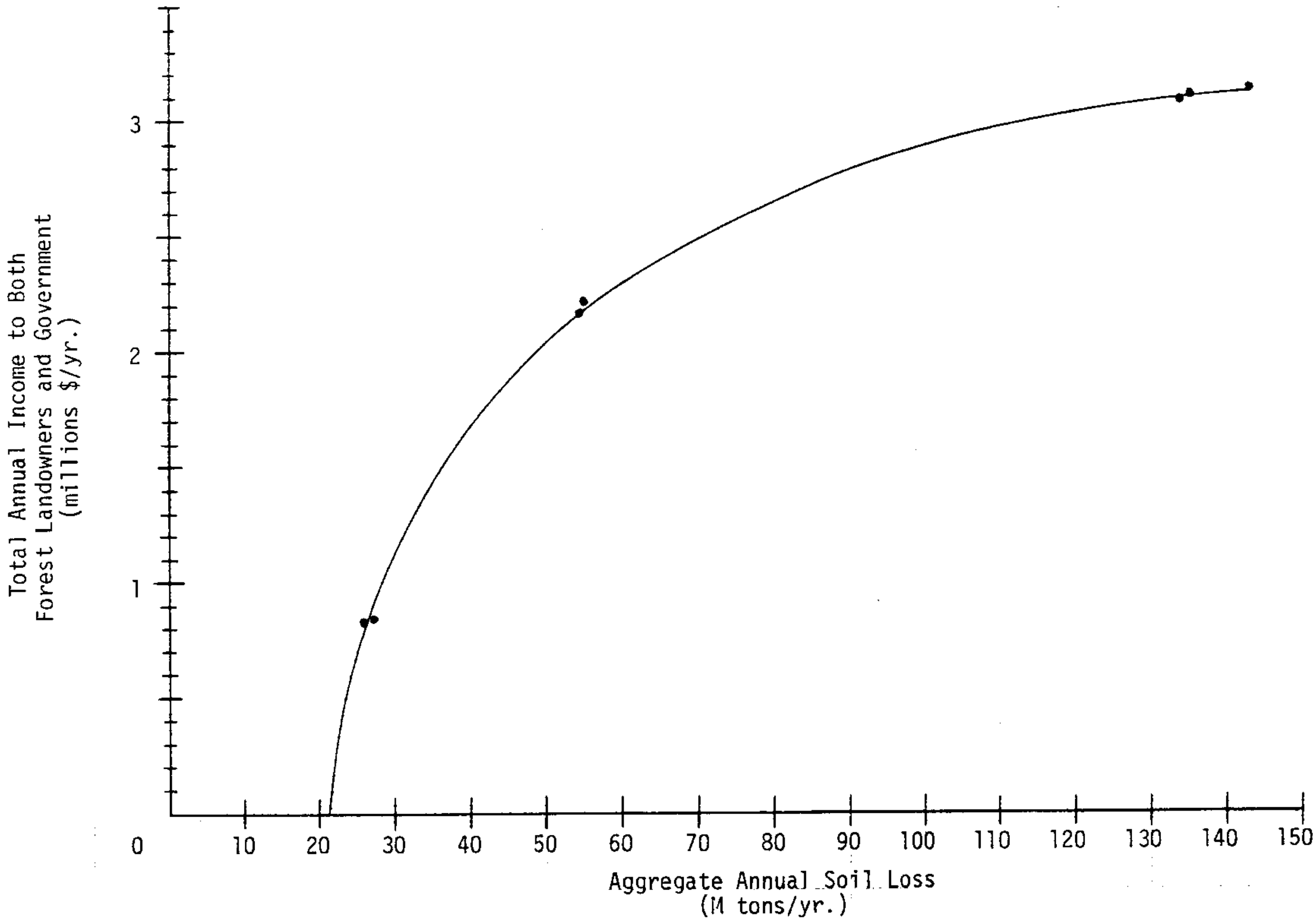

Figure (7). Societal income-soil loss tradeoff function associated with imposing a tax on excess soil loss.

maximum possible soil loss. It was on the basis of these differences that the amount of the subsidy was determined.

As was true in the case of the tax system, because of the low soil loss rates associated with the various management options, and the relatively small degree of variability between them, it was found that subsidy rates had to be increased to quite high levels before there was any appreciable shift to those options which result in less soil loss. Repetitive computer runs were made using annualized net present worth figures that were adjusted to reflect the payment of a subsidy for reduced soil loss at rates of $10, $20, $40, $60, and $80 per ton.[1/] The observed tradeoffs between soil loss, annual net income to forest landowners, annual timber yield, and government subsidy payments were as shown in Table (24).

As can be seen in the table, aggregate timber yield and soil loss exhibit the same relationship as has been observed in the analysis of the previous options. This clearly indicates that the effect of a subsidy is to encourage forest landowners to move to those less intensive forest management options that result in less soil loss, but also in less timber. Contrary to the trend observed in previous tables, annual net income to forest landowners increases with decreasing soil loss. This of course is due to the effect of the subsidy. From a societal standpoint, the increased income to forest landowners is offset by increases in governmental expenditures. Indeed, it's interesting to note that successive incremental decreases in soil loss are only achieved by making government subsidy payments which increase at an increasing rate. This is clearly evident from Figure (8).

[1/] The subsidy and revised annual net income figures used to perform this analysis are provided in Appendix D.

Table (24): Economic impacts of providing a subsidy for reducing soil loss from silvicultural activities in Cherokee County.

Subsidy Rate	Annual Soil Loss	Ann. Net Income from-[1] Forest Mgmt.	Government Subsidy Payments	Agg. Timber Yield Pine	Agg. Timber Yield Hardwood
($/Ton)	(Tons/Yr.)	($/Yr.)	($/Yr.)	(Ft^3/Yr.)	(Ft^3/Yr.)
0	143,718	3,135,311	0	40,826,860	4,897,030
10	134,362	3,371,510	250,731	39,747,017	4,897,030
20	55,148	4,296,043	2,090,099	34,004,694	4,897,030
40	54,529	6,454,251	4,186,495	33,646,529	4,897,030
60	26,886	8,782,437	7,927,758	15,873,789	4,897,030
80	26,169	11,420,330	10,574,043	15,873,789	4,733,771

1/ Includes the amounts of the government subsidy payments.

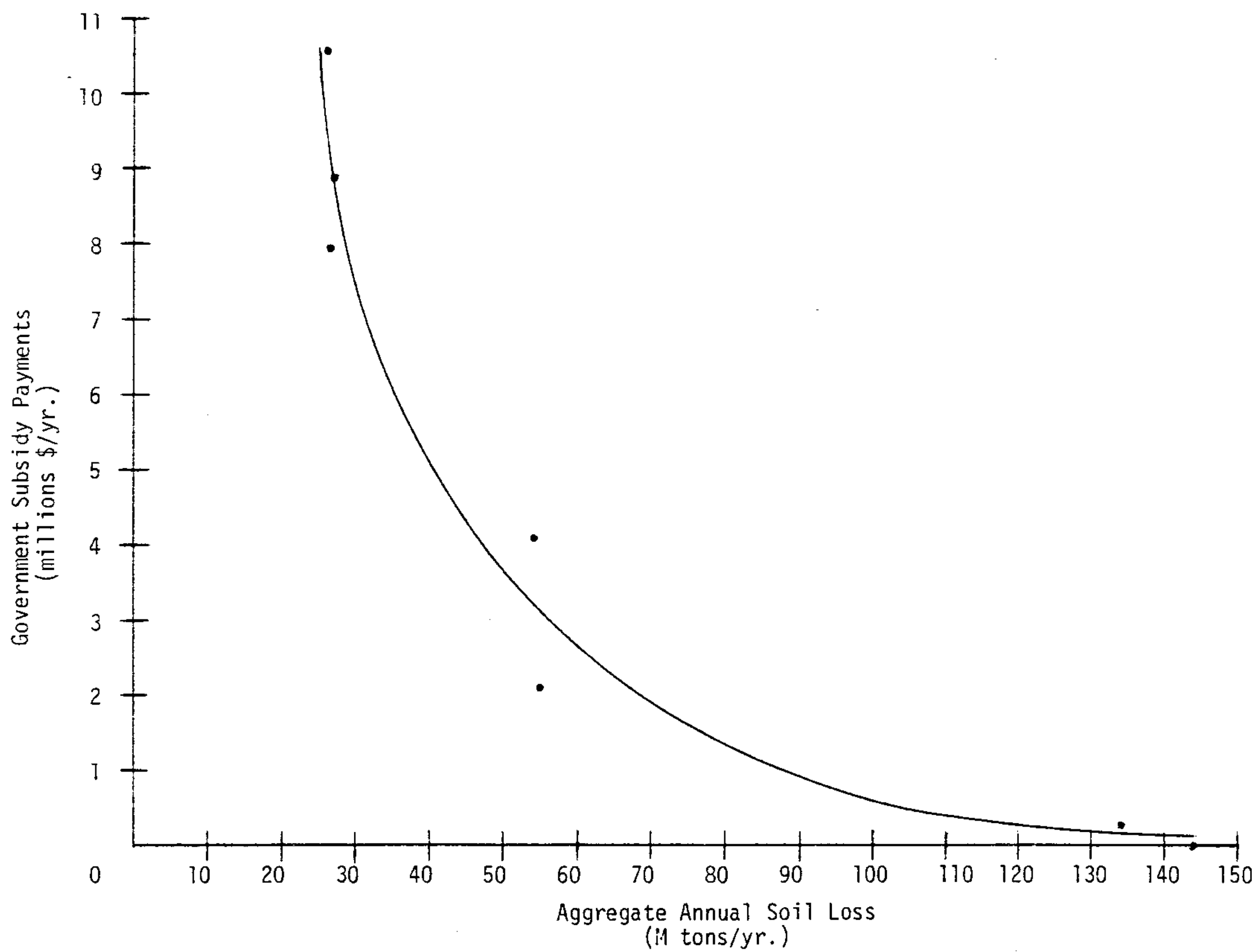

Figure (8). Subsidy payments required to achieve progressively lower levels of soil loss.

In Figure (9), an "income-soil loss" tradeoff function has been developed for the subsidy option. In constructing this function the amount of the subsidy payments themselves have been deducted from the total income accruing to forest landowners. If one compares this function with those previously developed for the other policy options, it is found to be virtually identical to that for a tax on excess soil loss. As already noted, the tax option appears to somewhat preferable to either an aggregate or per acre soil loss limit.

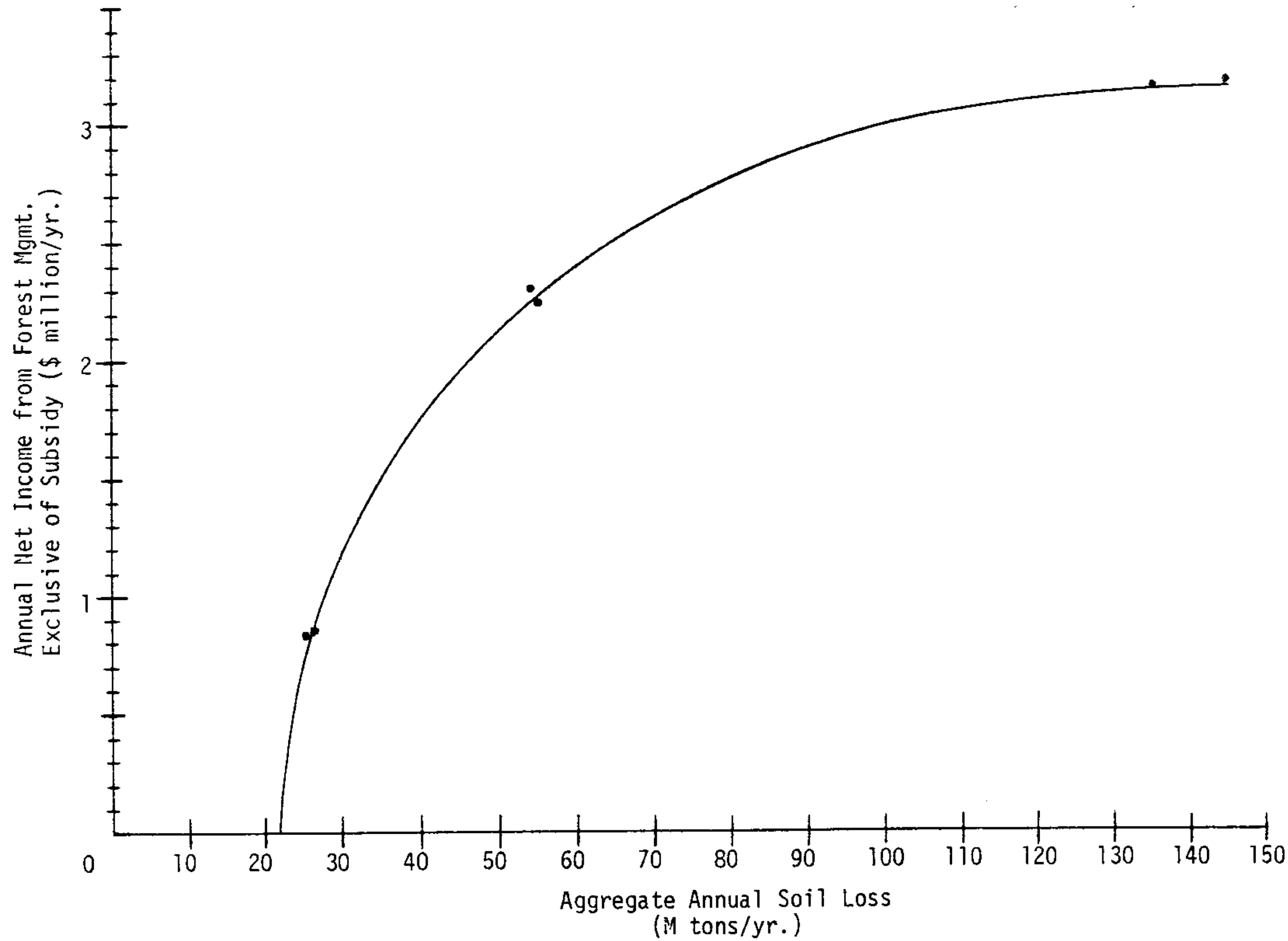

Figure (9). Income-soil loss tradeoff function associated with providing a subsidy for reduced soil loss.

CONCLUSIONS

The objectives of this study, as set forth in the introductory chapter, were: (1) to develop a methodology for estimating the economic impacts that would result from the imposition of alternative silviculture nonpoint source controls, and (2) to demonstrate how this methodology could be applied to a specific study area to facilitate decision-making about the economic rationality of imposing controls. For the most part it is felt that these objectives have been met. However, certain concluding observations remain to be made. These relate to: (1) limitations of the methodology developed in this study, (2) future research needs, and (3) the economic rationality of imposing silvicultural nonpoint source controls in the case of Cherokee County. The remainder of the chapter is organized around these three topics.

Methodological Limitations

Certain limitations associated with the methodology utilized in this study were set forth in the opening chapter. These pertained to the range of potential pollutants considered, the range of alternative control techniques considered, and the range of benefits and costs considered. At this point, now that the methodology itself has been presented, certain other limitations can be identified and discussed.

One such limitation concerns the fact that the present study has focused exclusively on the economic impacts resulting from the imposition of silvicultural nonpoint source controls. Furthermore, it has been implicitly assumed that the size of the commercial forest land base within the study area was fixed. In reality, 208 related controls are to be applied not only to forestry but to agriculture and other activities. Within such a context, it is not inconceivable that the controls will have differential impacts on different land uses. This could lead to shifts among land uses such as cropland, pastureland, and forestland. Such shifts have not been considered in the Cherokee County study.

However, they could be recognized by introducing appropriate crop production and grazing activities into the linear programming model.

A second limitation yet to be considered concerns the fact that the methodology employed in this study allows only one type of landowner response to increasingly stringent soil loss controls. Specifically, the landowner can respond by switching from one of the recognized timber management options to another. In certain situations this might be the appropriate response, however, in many instances we would expect the landowner to respond by simply modifying the way he performs certain forest practices. In other words, he could be expected to adopt conservation measures that would enable him to reduce soil loss while maintaining his original management option. At present the methodology does not allow for this type of response. This is largely unavoidable given our present understanding of the impacts of specific forest practices on soil loss.

One last limitation which needs to mentioned concerns the fact that the present methodology depicts economic tradeoffs from a theoretical situation which is probably not descriptive of real world conditions. This difficulty arises because the linear programming model used in this analysis presumes that forest landowners act so as to maximize the timber income received from their forest properties. While this assumption may be valid for industrial forest landowners, it is generally recognized that many nonindustrial private forest landowners do not behave as profit maximizers. The upshot of this, as previously implied, is that the actual pattern of forest land use in any given study area may well not correspond to the pattern determined -- by the LP model -- to be optimal when soil loss is unconstrained. As a consequence, the economic tradeoffs which would result from the imposition of controls might depart somewhat from those predicted by the analysis. This would be an extremely difficult problem to avoid; it would neccessitate being able to specify, for a given study area, how many acres within all of the soil management groups represented were actually being managed under each of the recognized management options.

Future Research Needs

A number of extensions of the type of analysis conducted in this study are readily apparent. One possibility which could prove to be quite enlightening would be to conduct essentially the same analysis under different assumptions as to production costs, product prices, and interest rates. Such a study would show how "sensitive" the tradeoffs between income, timber output, and soil loss are to changes in the values of these variables. Another possibility would be to apply the analysis to an area for which the sediment delivery ratios could be determined. This would eliminate the need to use soil loss as a proxy for sediment yields. In addition, if the required cost data were available, an assessment of off-site damages could be made.

Before really definitive economic studies can be undertaken, there is a great deal of fundamental watershed research which must be performed on forested watersheds in East Texas. Among the specific research needs are the following:

1.) Data pertaining to water quality from undisturbed forest watersheds. Such information is needed so that the impacts of man's land use activities can be isolated from variations attributable to natural causes.

2.) Data concerning the impacts which different forest practices will have on water quality under differing conditions of soil, slope, extent of revegetation, and so on. Some information of this nature is available, but very little pertains to southern coastal plain forests.

3.) Data on the effectiveness of the various conservation practices that might be used to control nonpoint source pollution from silvicultural activities. Such information is necessary in order to estimate the benefits, in physical terms, that would result from adopting such practices. With regard to this last item, information will also be required on the costs of utilizing the various conservation practices.

Economic Rationale For Controls

In regard to the results obtained by applying the proposed methodology to the Cherokee County study unit, each person is free to draw their own conclusions. Because the analysis was partial in nature, it is perhaps not possible to reach an irrefutable conclusion as to the economic rationality of imposing silvicultural nonpoint source controls. However, insights provided by the analysis have led the investigators to conclude that controls would probably not be economically justified. The principal reasons for reaching this conclusion are as follows:

1.) Soil loss from silvicultural activities, when expressed as an annual per acre average occurring over the length of a rotation or cutting cycle, is extremely low, even for the most intensive management options recognized in this analysis. The average annual per acre soil loss resulting from silvicultural activities, even when no restrictions were placed on the allowable level of soil loss, was only .37 tons/acre/yr. Of the 114 different "management option-soil management group" combinations recognized in this analysis, only one had an average annual per acre soil loss rate exceeding 1 ton/ac./yr. This was the short rotation pine plantation on soil management group 13. In actuality, such an intensive form of management would probably never be applied on this soil management group because of its marginal productivity. Furthermore, the fact must be kept in mind that these are soil loss, not sediment yield figures. Actual sediment yields could be substantially less than soil loss depending on the value of the sediment delivery ratio.

2.) The economic tradeoffs in the form of reduced income to forest landowners, and reduced timber yields, grow quite rapidly when an attempt is made to reduce soil loss below the level implied by the optimum solution to the LP model with soil loss unconstrained. This is evident from the shape of the tradeoff functions for each policy option. Given the small volumes of soil loss resulting from forestry activities, it's unlikely that the benefits to be obtained by reducing soil loss even further would offset the costs associated with achieving these lower levels.

LITERATURE CITED

Barron, Edwin H. 1977. Texas Forest Resource Harvest Trends 1976. Texas Forest Service Publication No. 115. 22 pp.

Dissmeyer, George E. 1977. Unpublished data on CP factors for selected forest practices applied in the coastal plain of East Texas. Information obtained by personal communication.

Dissmeyer, George E. and George R. Foster. 1977. Preliminary Procedure for Soil Loss Prediction on Forest Land. Unpublished manuscript. 14 pp.

Dissmeyer, George E. and Richard F. Stump. 1977. Predicted Erosion Rates for Forest Management Activities and Conditions Sampled in the Southeast. Unpublished manuscript. 9 pp.

Duerr, William A. 1960. Fundamentals of Forestry Economics. McGraw-Hill Book Company. New York, New York.

Earles, J. M. 1976. Forest Statistics for East Texas Pineywoods Counties. Southern Forest Experiment Station, New Orleans, Louisiana. 40 pp. (USDA, Forest Service Resource Bulletin SO-60).

Everett, H. W. and W. L. Miller. 1975. Sectoral and Regional Economic Impact of Controlling Nonpoint Pollution in Forested Areas. Water Resources Research Center, Purdue University. 83 pp. (Technical Report No. 53).

Freeman, Billy G. and Curtis F. Lard. 1970. A User's Guide to Linear Programming and the IBM MPS-360 Computer Routine. Department of Agricultural Economics, Texas A&M University. 47 pp. (Departmental Technical Report 70-2).

Johnson, R. L. 1968. Thinning Improves Growth in Stagnated Sweetgum Stands. USDA, Forest Service. Southern Forest Experiment Station Research Note SO-82. 5 pp.

Lee, Ming T. and Karl L. Guntermann. 1976. A Procedure for Estimating Off-Site Sediment Damage Costs and an Empirical Test. Water Resources Bulletin. 12(3), pp. 561-575.

Murphy, P. A. 1976. East Texas Forests -- status and trends. Southern Forest Experiment Station, New Orleans, LA. 25 pp. (USDA Forest Service Resource Bulletin SO-61).

Narayanan, A. S., M. T. Lee, and E. R. Swanson. 1974. Economic Analysis of Erosion and Sedimentation -- Lake Glendale Watershed. Department of Agricultural Economics, University of Illinois in cooperation with Illinois Institute of Environmental Quality. 18 pp. (IIEQ Document No. 74-40).

Nelson, Thomas C. 1963. Basal Area Growth of Natural Loblolly Pine Stands. USDA, Forest Service. Southeastern Forest Experiment Station Research Note SE-10. 4 pp.

Schumacher, F. X. and T. S. Coile. 1960. Growth and Yields of Natural Stands of the Southern Pines. T. S. Coile, Inc. Durham, N. C.

Soil Conservation Service. 1959. Soil Survey of Cherokee County, Texas. Report by Irvin C. Mowery and Harvey Oakes. U.S. Government Printing Office. 65 pp.

Soil Conservation Service. 1977. Procedure for Computing Sheet and Rill Erosion on Project Areas. Technical Release No. 51. 17 pp.

Texas Forest Service. 1977. Texas Forest Industries Directory -- 1977. 18 pp.

Williams, David L. and William C. Hopkins. 1968. Converting Factors for Southern Pine Products. Agricultural Experiment Station, Louisiana State University. Bulletin No. 626. 89 pp.

Winters, Robert K. and James G. Osborn. 1935. Growth and Yield of Second-Growth Red Gum in Fully Stocked Stands on Alluvial Lands in the South. USDA, Forest Service. Southern Forest Experiment Station Occasional Paper 54. 12 pp.

Wischmeier, Walter H. and Dwight D. Smith. 1965. Predicting Rainfall-Erosion Losses from Cropland East of the Rocky Mountains. Agriculture Handbook No. 282. U.S. Government Printing Office. 47 pp.

Appendix A

Appendix A. K, LS, and T values for the different soils found within Cherokee County. (Source: Data provided by Soil Conservation Service.)

Soil	K Value[1/]	L/S Ratio	LS Value	T Value[2/]
Soil Management Group (1)				
Woden	.20	150/.5	.11	5
Soil Management Group (2)				
Bowie fsl g.s.	.32	400/3	.43	5
Elrose fsl g.s.	.24	200/1.5	.20	5
Nacogdoches fsl g.s.	.32	200/1.5	.20	5
Nacogdoches cl g.s.	.32	200/1.5	.20	5
Ruston fsl	.32	400/3	.43	4
Soil Management Group (3)				
Lilbert lfs g.s.	.20	500/1	.20	5
Briley lfs g.s.	.20	200/2	.24	5
Soil Management Group (4)				
Bowie fsl s.	.32	400/5	1.07	5
Elrose fsl s.	.24	80/5	.47	5
Nacogdoches fsl s.	.32	150/5	.65	5
Ruston fsl s.	.32	400/3	.43	4
Soil Management Group (5)				
Lilbert lfs s.	.20	300/4	.62	5
Briley lfs s.	.20	200/2	.24	5
Soil Management Group (6)				
Sacul fsl g.s.	.32	200/3	.35	3
Woodtell fsl g.s.	.43	100/1	.12	4
Soil Management Group (7)				
Bowie fsl s.e.	.32	400/5	1.07	5
Cuthbert fsl s.	.32	200/12	2.55	3
Ruston fsl s.e.	.32	400/3	.43	4
Soil Management Group (8)				
Sacul fsl s.	.32	200/6	.95	3
Nacogdoches fsl s.e.	.32	150/5	.65	5
Nacogdoches cl s. & s.e.	.32	150/5	.65	5

Appendix A. Continued.

Soil	K Value	L/S Ratio	LS Value	T Value
Soil Management Group (9)				
Betis lfs n.l.	.17	300/1	.17	5
Bienville lfs	.20	200/5	.12	5
Bienville lfs n.l.	.20	200/2	.24	5
Darco lfs n.l.	.17	300/2	.27	5
Soil Management Group (10)				
Betis lfs s.	.17	150/5	.65	5
Bienville lfs s.	.20	200/5	.12	5
Darco lfs s.	.17	200/5	.75	5
Soil Management Group (11)				
LaCerda cl	.32	100/2.5	.24	5
LaCerda cl g.s.	.32	20/4	.21	5
Soil Management Group (12)				
Lilbert lfs s.e.	.20	300/4	.62	5
Betis lfs s.e.	.17	150/5	.65	5
Darco lfs s.e.	.17	80/11	1.42	5
Soil Management Group (13)				
Sacul fsl s.e.	.32	200/6	.95	3
Sacul fsl s.s. & s.s.e.	.32	400/12	3.60	3
Sacul fcl s.s. & s.e.	.32	400/12	3.60	3
Bub-Trawick complex	.32	60/25	4.56	2
Cuthbert fsl s.s. & s.s.e.	.32	200/12	2.55	3
Trawick s.s.	.37	80/10	1.22	4
Trawick s.s.e.	.37	80/10	1.22	4
LaCerda cl s.	.32	100/2.5	.24	5
LaCerda c n.l.	.32	20/4	.21	5
Woodtell fsl s. & s.e.	.43	100/5	.53	4
Soil Management Group (14)				
Darco lfs s.s. & s.s.e.	.17	80/11	1.42	5
Bienville lfs s.s.	.20	200/5	.12	5
Darco lfs s.s.	.17	80/11	1.42	5
Tenaha s.s.	.17	100/12	1.80	3
Soil Management Group (15)				
Tuscosso fsl	.28	200/.1	.09	5
Iuka fsl	.24	100/.1	.07	5
Bienville lfs	.20	200/2	.24	5

Appendix A. Continued.

Soil	K Value	L/S Ratio	LS Value	T Value
Soil Management Group (16)				
Tuscosso cl	.32	200/.1	.09	5
Marietta cl	.28	100/.1	.07	5
Soil Management Group (17)				
Alazan fsl	.43	100/1	.12	5
Alazan mound	.43	50/2	.16	5
Soil Management Group (18)				
Mantachie cl	.28	500/.1	.12	5
Mantachie fsl	.28	500/.1	.12	5
Percilla soils	.28	50/.05	.05	5
Soil Management Group (19)				
Alto cl	.32	200/.8	.13	5
Alto l	.32	300/1	.17	5
Soil Management Group (20)				
Marsh	--	--	--	--

[1/] All the published K values should be multiplied by .45 to account for the fact that forest soils are not regularly tilled and consequently are less readily erodible.

[2/] Soil loss tolerance values which specify the maximum rate of soil erosion that will permit high level crop productivity to be sustained economically and indefinitely.

APPENDIX B

Appendix B: Estimated average annual timber yields for all management option-site index combinations.

Management Options	Yield Over Complete Rotation or Cutting Cycle				Estimated Annual Yield			
	SI=70 ($ft.^3/ac.$)	SI=80 ($ft^3/ac.$)	SI=90 ($ft^3/ac.$)	SI=100 ($ft^3/ac.$)	SI=70 ($ft^3/ac.$)	SI=80 ($ft^3/ac.$)	SI=90 ($ft^3/ac.$)	SI=100 ($ft^3/ac.$)
Short rotation pine plantation	2010	2439	2874	--	80.4	97.6	115.0	--
Medium rotation pine plantation	4385	5679	7412	--	125.3	162.2	211.8	--
Long rotation pine plantation	5926	8575	10099	--	98.8	142.9	168.3	--
Short rotation pine nat. stand	2520	3232	4207	--	72.0	92.3	120.2	--
Long rotation pine nat. stand	4562	5966	7880	--	65.2	85.2	112.6	--
Short rotation hardwood nat. stand	--	--	6077	7512	--	--	121.5	150.2
Long rotation hardwood nat. stand	--	--	10467	12352	--	--	130.8	154.4
Custodial mgmt. (pine site)	1200	1200	1200	--	60.0	60.0	60.0	--
Custodial mgmt. (hdw. site)	--	--	1200	1200	--	--	60.0	60.0
Undisturbed forest	--	--	--	--	--	--	--	--

APPENDIX C

Appendix C: Current annualized return coefficients adjusted for tax on excess soil loss.

Mgmt. Option Soil Mgmt. Group Combination	Excess Soil-Loss	Current Annual Return	Adjusted Current Annualized Return (CAR) Coefficients ($/Ac./Yr.)									
			Tax Rate = $2		Tax Rate = $4		Tax Rate = $6		Tax Rate = $8		Tax Rate = $10	
	(Tn./Ac./Yr)	($/Ac./Yr.)	(Tax)	(CAR)	(Tax)	(CAR)	(Tax)	(CAR)	(Tax)	(CAR)	(Tax)	(CAR)
SPP 1	.0219	5.67	.04	5.63	.09	5.58	.13	5.54	.18	5.49	.22	5.45
SPP 2	.0991	4.14	.20	3.94	.40	3.74	.59	3.55	.79	3.35	.99	3.15
SPP 3	.0418	4.14	.08	4.06	.17	3.97	.25	3.89	.33	3.81	.42	3.72
SPP 4	.2385	4.14	.48	3.66	.95	3.19	1.43	2.71	1.91	2.23	2.38	1.76
SPP 5	.1115	4.14	.22	3.92	.45	3.69	.67	3.47	.89	3.25	1.12	3.02
SPP 6	.0837	2.45	.17	2.28	.33	2.12	.50	1.95	.67	1.78	.84	1.61
SPP 7	.4647	4.14	.93	3.21	1.86	2.28	2.79	1.35	3.72	.42	4.65	-.51
SPP 8	.2695	4.14	.54	3.60	1.08	3.06	1.62	2.52	2.16	1.98	2.70	1.44
SPP 9	.0407	4.14	.08	4.06	.16	3.98	.24	3.90	.33	3.81	.41	3.73
SPP 10	.1221	2.45	.24	2.21	.49	1.96	.73	1.72	.98	1.47	1.22	1.23
SPP 11	.0712	2.45	.14	2.31	.28	2.17	.43	2.02	.57	1.88	.71	1.74
SPP 12	.1254	4.14	.25	3.89	.50	3.64	.75	3.39	1.00	3.14	1.25	2.39
SPP 13	.9393	2.45	1.88	.57	3.76	-1.31	5.64	-3.19	7.51	-5.06	9.39	-6.94
SPP 14	.2708	2.45	.54	1.91	1.08	1.37	1.62	.83	2.17	.28	2.71	-.26
MPP 1	.0200	14.77	.04	14.73	.08	14.69	.12	14.65	.16	14.61	.20	14.57
MPP 2	.0907	10.33	.18	10.15	.36	9.97	.54	9.79	.73	9.60	.91	9.40
MPP 3	.0382	10.33	.08	10.25	.15	10.13	.23	10.10	.31	10.02	.38	9.95
MPP 4	.2183	10.33	.44	9.89	.87	9.46	1.31	9.02	1.75	8.58	2.18	8.15
MPP 5	.1021	10.33	.20	10.13	.41	9.92	.61	9.72	.82	9.51	1.02	9.31
MPP 6	.0766	6.50	.15	6.35	.31	6.19	.46	6.04	.61	5.89	.77	5.73
MPP 7	.4253	10.33	.85	9.48	1.70	8.63	2.55	7.78	3.40	6.93	4.25	6.08
MPP 8	.2466	10.33	.49	9.84	.99	9.34	1.48	8.85	1.97	8.36	2.47	7.86
MPP 9	.0373	10.33	.07	10.26	.15	10.18	.22	10.11	.30	10.03	.37	9.96
MPP 10	.1118	6.50	.22	6.28	.45	6.05	.67	5.83	.89	5.61	1.12	5.38
MPP 11	.0652	6.50	.13	6.37	.26	6.24	.39	6.11	.52	5.98	.65	5.85

Appendix C: Continued.

Mgmt. Option Soil Mgmt. Group Combination	Excess Soil-Loss	Current Annual Return	Adjusted Current Annualized Return (CAR) Coefficients ($/Ac./Yr.)									
			Tax Rate = $20		Tax Rate = $40		Tax Rate = $60		Tax Rate = $80			
	(Tn./Ac./Yr	($/Ac./Yr.)	(Tax)	(CAR)	(Tax)	(CAR)	(Tax)	(CAR)	(Tax)	(CAR)		
SPP 1	.0219	5.67	.44	5.23	.88	4.79	1.31	4.36	1.75	3.92		
SPP 2	.0991	4.14	1.98	2.16	3.96	.18	5.95	-1.81	7.93	-3.79		
SPP 3	.0412	4.14	.84	3.30	1.67	2.47	2.51	1.63	3.34	.80		
SPP 4	.2385	4.14	4.77	-.63	9.54	-5.31	14.31	-10.17	19.08	-14.94		
SPP 5	.1115	4.14	2.23	1.91	4.46	-.32	6.69	-2.55	8.92	-4.78		
SPP 6	.0837	2.45	1.67	.78	3.35	-.90	5.02	-2.57	6.70	-4.25		
SPP 7	.4647	4.14	9.29	-5.15	18.59	-14.45	27.88	-23.74	37.18	-33.04		
SPP 8	.2695	4.14	5.39	-1.25	10.78	-6.64	16.17	-12.03	21.56	-17.42		
SPP 9	.0407	4.14	.81	3.33	1.63	2.51	2.44	1.70	3.26	.88		
SPP 10	.1221	2.45	2.44	.01	4.88	-2.43	7.33	-4.88	9.77	-7.32		
SPP 11	.0712	2.45	1.42	1.03	2.85	-.40	4.27	-1.82	5.70	-3.25		
SPP 12	.1254	4.14	2.51	1.63	5.02	-.88	7.52	-3.38	10.03	-5.89		
SPP 13	.9393	2.45	18.79	-16.34	37.57	-35.12	56.36	-53.91	75.14	-72.69		
SPP 14	.2708	2.45	5.42	-2.97	10.83	-8.38	16.25	-13.80	21.66	-19.21		
MPP 1	.0200	14.77	.40	14.37	.80	13.97	1.20	13.57	1.60	13.17		
MPP 2	.0907	10.33	1.81	8.52	3.63	6.70	5.44	4.89	7.26	3.07		
MPP 3	.0382	10.33	.76	9.57	1.53	8.80	2.29	8.04	3.06	7.27		
MPP 4	.2183	10.33	4.37	5.96	8.73	1.60	13.10	-2.77	17.46	-7.13		
MPP 5	.1021	10.33	2.04	8.29	4.08	6.25	6.13	4.20	8.17	2.16		
MPP 6	.0766	6.50	1.53	4.97	3.06	3.44	4.60	1.90	6.13	.37		
MPP 7	.4253	10.33	8.51	1.82	17.01	-6.68	25.52	-15.19	34.02	-23.69		
MPP 8	.2466	10.33	4.93	5.40	9.36	.47	14.80	-4.47	19.73	-9.40		
MPP 9	.0373	10.33	.75	9.58	1.49	8.84	2.24	8.09	2.98	7.35		
MPP 10	.1118	6.50	2.24	4.26	4.47	2.03	6.71	-.21	8.94	-2.44		
MPP 11	.0652	6.50	1.30	5.20	2.61	3.89	3.91	2.59	5.22	1.28		

Appendix C: Continued.

Mgmt. Option Soil Mgmt. Group Combination	Excess Soil-Loss	Current Annual Return	Adjusted Current Annualized Return (CAR) Coefficients ($/Ac./Yr.)									
			Tax Rate = $2		Tax Rate = $4		Tax Rate = $6		Tax Rate = $8		Tax Rate = $10	
	(Tn./Ac./Yr	($/Ac./Yr.)	(Tax)	(CAR)	(Tax)	(CAR)	(Tax)	(CAR)	(Tax)	(CAR)	(Tax)	(CAR)
MPP 12	.1148	10.33	.23	10.10	.46	9.87	.69	9.64	.92	9.41	1.15	9.18
MPP 13	.8597	6.50	1.72	4.78	3.44	3.06	5.16	1.34	6.88	-.38	8.60	-2.10
MPP 14	.2479	6.50	.50	6.00	.99	5.51	1.49	5.01	1.98	4.52	2.48	4.02
LPP 1	.0182	11.94	.04	11.90	.07	11.87	.11	11.83	.15	11.79	.18	11.76
LPP 2	.0823	8.58	.16	8.42	.33	8.25	.49	8.09	.66	7.92	.82	7.76
LPP 3	.0347	8.58	.07	8.51	.14	8.44	.21	8.37	.28	8.30	.35	8.23
LPP 4	.1981	8.58	.40	8.18	.79	7.79	1.19	7.39	1.58	7.00	1.98	6.60
LPP 5	.0926	8.58	.19	8.39	.37	8.21	.56	8.02	.74	7.84	.93	7.65
LPP 6	.0695	5.63	.14	5.49	.28	5.35	.42	5.21	.56	5.07	.70	4.93
LPP 7	.3859	8.58	.77	7.81	1.54	7.04	2.32	6.26	3.09	5.49	3.86	4.72
LPP 8	.2238	8.58	.45	8.13	.90	7.68	1.34	7.24	1.79	6.79	2.24	6.34
LPP 9	.0338	8.58	.07	8.51	.14	8.44	.20	8.38	.27	8.31	.34	8.24
LPP 10	.1014	5.63	.20	5.43	.41	5.22	.61	5.02	.81	4.82	1.01	4.62
LPP 11	.0591	5.63	.12	5.51	.24	5.39	.35	5.28	.47	5.16	.59	5.04
LPP 12	.1042	8.58	.21	8.37	.42	8.16	.63	7.95	.83	7.75	1.04	7.54
LPP 13	.7801	5.63	1.56	4.07	3.12	2.51	4.68	.95	6.24	-.61	7.08	-2.17
LPP 14	.2249	5.63	.45	5.18	.90	4.73	1.35	4.28	1.80	3.83	2.25	3.38
SPN 1	.0193	11.80	.04	11.76	.08	11.72	.12	11.68	.15	11.65	.19	11.61
SPN 2	.0873	9.42	.17	9.25	.35	9.07	.52	8.90	.70	8.72	.87	8.55
SPN 3	.0368	9.42	.07	9.35	.15	9.27	.22	9.20	.29	9.13	.37	9.05
SPN 4	.2102	9.42	.42	9.00	.84	8.58	1.26	8.16	1.68	7.74	2.10	7.32
SPN 5	.0983	9.42	.20	9.22	.39	9.03	.59	8.83	.79	8.63	.98	8.44
SPN 6	.0738	7.23	.15	7.08	.30	6.93	.44	6.79	.59	6.64	.74	6.49
SPN 7	.4095	9.42	.82	8.60	1.64	7.78	2.46	6.96	3.28	6.14	4.10	5.32
SPN 8	.2375	9.42	.48	8.94	.95	8.47	1.42	8.00	1.90	7.52	2.38	7.04

Appendix C: Continued.

Mgmt. Option Soil Mgmt. Group Combination	Excess Soil-Loss	Current Annual Return	Adjusted Current Annualized Return (CAR) Coefficients ($/Ac./Yr.)									
			Tax Rate = $20		Tax Rate = $40		Tax Rate = $60		Tax Rate = $80			
	(Tn./Ac./Yr)	($/Ac./Yr.)	(Tax)	(CAR)	(Tax)	(CAR)	(Tax)	(CAR)	(Tax)	(CAR)		
MPP 12	.1148	10.33	2.30	8.03	4.59	5.74	6.89	3.44	9.18	1.15		
MPP 13	.8597	6.50	17.19	-10.69	34.39	-27.39	51.58	-45.08	68.78	-62.28		
MPP 14	.2479	6.50	4.96	1.54	9.92	-3.42	14.87	-8.37	19.83	-13.33		
LPP 1	.0182	11.94	.36	11.58	.73	11.21	1.09	10.85	1.46	10.48		
LPP 2	.0823	8.58	1.65	6.93	3.29	5.29	4.94	3.64	6.58	1.73		
LPP 3	.0347	8.58	.69	7.39	1.39	7.19	2.08	6.50	2.78	5.80		
LPP 4	.1981	8.58	3.96	4.62	7.92	1.29	11.87	-3.29	15.85	-7.27		
LPP 5	.0926	8.58	1.85	6.73	3.70	4.88	5.56	3.02	7.41	1.17		
LPP 6	.0695	5.63	1.39	4.24	2.78	2.85	4.17	1.46	5.56	.07		
LPP 7	.3859	8.58	7.72	.86	15.44	-6.86	23.15	-14.57	30.78	-22.20		
LPP 8	.2238	8.58	4.48	4.10	8.95	-.37	13.43	-4.85	17.90	-9.32		
LPP 9	.0338	8.58	.68	7.90	1.35	7.23	2.03	6.55	2.70	5.88		
LPP 10	.1014	5.63	2.03	3.60	4.06	1.57	6.08	-.45	8.11	-2.48		
LPP 11	.0591	5.63	1.18	4.45	2.36	3.27	3.55	2.08	4.73	.90		
LPP 12	.1042	8.58	2.08	6.50	4.17	4.41	6.25	2.33	8.34	.24		
LPP 13	.7801	5.63	15.60	-9.97	31.20	-25.57	46.81	-41.18	62.41	-56.78		
LPP 14	.2249	5.63	4.50	1.13	9.00	-3.37	13.49	-7.86	17.99	-12.36		
SPN 1	.0193	11.80	.39	11.41	.77	11.03	1.16	10.64	1.54	10.26		
SPN 2	.0873	9.42	1.75	7.67	3.49	5.93	5.24	4.18	6.98	2.44		
SPN 3	.0368	9.42	.74	8.68	1.47	7.95	2.21	7.21	2.94	6.48		
SPN 4	.2102	9.42	4.20	5.22	8.41	1.01	12.61	-3.19	16.82	-7.40		
SPN 5	.0983	9.42	1.97	7.45	3.93	5.49	5.90	3.52	7.86	1.56		
SPN 6	.0738	7.23	1.48	5.75	2.95	4.28	4.43	2.80	5.90	1.33		
SPN 7	.4095	9.42	8.19	1.23	16.38	-6.96	24.57	-15.15	32.76	-23.34		
SPN 8	.2375	9.42	4.75	4.67	9.50	-.08	14.25	-4.83	19.00	-9.58	-	

Appendix C: Continued.

Mgmt. Option Soil Mgmt. Group Combination	Excess Soil-Loss	Current Annual Return	Adjusted Current Annualized Return (CAR) Coefficients ($/Ac./Yr.)									
			Tax Rate = $2		Tax Rate = $4		Tax Rate = $6		Tax Rate = $8		Tax Rate = $10	
	(Tn./Ac./Yr)	($/Ac./Yr.)	(Tax)	(CAR)	(Tax)	(CAR)	(Tax)	(CAR)	(Tax)	(CAR)	(Tax)	(CAR)
SPN 9	.0359	9.42	.07	9.35	.14	9.28	.22	9.26	.29	9.13	.36	9.06
SPN 10	.1076	7.23	.22	7.01	.43	6.80	.65	6.58	.86	6.37	1.08	6.15
SPN 11	.0628	7.23	.13	7.10	.25	6.98	.38	6.85	.50	6.73	.63	6.60
SPN 12	.1105	9.42	.22	9.20	.44	8.98	.66	8.76	.88	8.54	1.10	8.32
SPN 13	.8278	7.23	1.66	5.57	3.31	3.92	4.97	2.26	6.62	.61	8.28	-1.05
SPN 14	.2387	7.23	.48	6.75	.95	6.28	1.43	5.80	1.91	5.32	2.39	4.84
LPN 1	.0174	11.21	.03	11.18	.07	11.14	.10	11.11	.14	11.07	.17	11.04
LPN 2	.0789	9.00	.16	8.84	.32	8.68	.47	8.53	.63	8.37	.79	8.21
LPN 3	.0333	9.00	.07	8.93	.13	8187	.20	8.80	.27	8.73	.33	8.67
LPN 4	.1900	9.00	.38	8.62	.76	8.24	1.14	7.86	1.52	7.48	1.90	7.10
LPN 5	.0889	9.00	.18	8.82	.36	8.64	.53	8.47	.71	8.29	.89	8.11
LPN 6	.0667	7.14	.13	7.01	.27	6.87	.40	6.74	.53	6.61	.67	6.47
LPN 7	.3701	9.00	.74	8.26	1.48	7.52	2.22	6.78	2.96	6.04	3.70	5.30
LPN 8	.2147	9.00	.43	8.57	.86	8.14	1.29	7.71	1.72	7.28	2.15	6.85
LPN 9	.0325	9.00	.06	8.94	.13	8.87	.20	8.80	.26	8.74	.32	8.68
LPN 10	.0973	7.14	.19	6.95	.39	6.75	.58	6.56	.78	6.36	.97	6.17
LPN 11	.0567	7.14	.11	7.03	.23	6.91	.34	6.80	.45	6.69	.57	6.57
LPN 12	.0999	9.00	.20	8.80	.40	8.60	.60	8.40	.80	82.0	1.00	8.00
LPN 13	.7482	7.14	1.50	5.64	2.99	4.15	4.49	2.65	5.99	1.15	7.48	-.34
LPN 14	.2158	7.14	.43	6.71	.86	6.28	1.29	5.85	1.73	5.41	2.16	4.98
SHN 15	.0166	1.99	.03	1.96	.07	1.92	.10	1.89	.13	1.86	.17	1.82
SHN 16	.0157	1.99	.03	1.96	.06	1.93	.09	1.90	.13	1.86	.16	1.83
SHN 17	.0393	1.13	.08	1.05	.16	.97	.24	.89	.31	.82	.39	.74
SHN 18	.0246	1.13	.05	1.08	.10	1.13	.15	.98	.20	.93	.25	.88
LHN 15	.0148	1.65	.03	1.62	.06	1.59	.09	1.56	.12	1.53	.15	1.50

Appendix C: Continued.

Mgmt. Option Soil Mgmt. Group Combination	Excess Soil-Loss	Current Annual Return	Adjusted Current Annualized Return (CAR) Coefficients ($/Ac./Yr.)									
			Tax Rate = $20		Tax Rate = $40		Tax Rate = $60		Tax Rate = $80			
	(Tn./Ac./Yr)	($/Ac./Yr.)	(Tax)	(CAR)	(Tax)	(CAR)	(Tax)	(CAR)	(Tax)	(CAR)		
SPN 9	.0359	9.42	.72	8.70	1.44	7.98	2.15	7.27	2.87	6.55		
SPN 10	.1076	7.23	2.15	5.08	4.30	2.93	6.46	.77	8.61	-1.38		
SPN 11	.0628	7.23	1.26	5.97	2.51	4.72	3.77	3.46	5.02	2.21		
SPN 12	.1105	9.42	2.21	7.21	4.42	5.00	6.63	2.79	8.84	.58		
SPN 13	.8278	7.23	16.56	-9.33	33.11	-25.88	49.67	-42.44	66.22	-58.99		
SPN 14	.2387	7.23	4.77	2.46	9.55	-2.32	14.32	-7.09	19.10	-11.87		
LPN 1	.0174	11.21	.35	10.86	.70	10.51	1.04	10.17	1.39	9.82		
LPN 2	.0789	9.00	1.58	7.42	3.16	5.84	4.73	4.27	6.31	2.69		
LPN 3	.0333	9.00	.67	8.33	1.33	7.67	2.00	7.00	2.66	6.34		
LPN 4	.1900	9.00	3.80	5.20	7.60	1.40	11.40	-2.40	15.20	-6.20		
LPN 5	.0889	9.00	1.78	7.22	3.56	5.44	5.33	3.67	7.11	1.89		
LPN 6	.0667	7.14	1.33	5.81	2.67	4.47	4.00	3.14	5.34	1.80		
LPN 7	.3701	9.00	7.40	1.60	14.80	-5.80	22.21	-13.21	29.61	-20.61		
LPN 8	.2147	9.00	4.29	4.71	8.59	.41	12.88	-3.88	17.18	-8.18		
LPN 9	.0325	9.00	.65	8.35	1.30	7.70	1.95	7.05	2.60	6.40		
LPN 10	.0973	7.14	1.95	5.19	3.89	3.25	5.84	1.30	7.78	-.64		
LPN 11	.0567	7.14	1.13	6.01	2.27	4.87	3.40	3.74	4.54	2.60		
LPN 12	.0999	9.00	2.00	7.00	4.00	5.00	5.99	3.01	7.99	1.01		
LPN 13	.7482	7.14	14.96	-7.82	29.93	-22.79	44.89	-37.75	59.86	-52.72		
LPN 14	.2158	7.14	4.32	2.82	8.63	-1.49	12.95	-5.81	17.26	-10.12		
SHN 15	.0166	1.99	.33	1.66	.66	1.33	1.00	.00	1.33	.66		
SHN 16	.0157	1.99	.31	1.68	.63	1.36	.94	1.05	1.26	.73		
SHN 17	.0393	1.13	.79	.34	1.57	-.44	2.36	-1.23	3.14	-2.01		
SHN 18	.0246	1.13	.49	.64	.98	.15	1.48	-.35	1.97	-.84		
LHN 15	.0148	1.65	.30	1.35	.59	1.06	.89	.76	1.18	.47		

Appendix C: Continued.

Mgmt. Option Soil Mgmt. Group Combination	Excess Soil-Loss	Current Annual Return	Adjusted Current Annualized Return (CAR) Coefficients ($/Ac./Yr.)									
			Tax Rate = $2		Tax Rate = $4		Tax Rate = $6		Tax Rate = $8		Tax Rate = 10	
	(Tn./Ac./Yr)	($/Ac./Yr.)	(Tax)	(CAR)	(Tax)	(CAR)	(Tax)	(CAR)	(Tax)	(CAR)	(Tax)	(CAR)
LHN 16	.0140	1.65	.03	1.62	.06	1.59	.08	1.57	.11	1.54	.14	1.51
LHN 17	.0350	1.12	.07	1.05	.14	.98	.21	.91	.28	.84	.35	.77
LHN 18	.0219	1.12	.04	1.08	.09	1.03	.13	.99	.18	.94	.22	.90
CM 1	.0160	3.81	.03	3.78	.06	3.75	.10	3.71	.13	3.68	.16	3.65
CM 2	.0722	3.81	.14	3.67	.29	3.52	.43	3.38	.58	3.23	.72	3.09
CM 3	.0304	3.81	.06	3.75	.12	3.69	.18	3.63	.24	3.57	.30	3.51
CM 4	.1738	3.81	.35	3.46	.70	3.11	1.04	2.77	1.39	2.42	1.74	2.07
CM 5	.0183	3.81	.16	3.65	.33	3.48	.49	3.32	.65	3.16	.81	3.00
CM 6	.0610	3.81	.12	3.69	.24	3.57	.37	3.44	.49	3.32	.61	3.20
CM 7	.3388	3.81	.68	3.13	1.36	2.45	2.03	1.78	2.71	1.10	3.39	.42
CM 8	.1964	3.81	.39	3.42	.79	3.02	1.18	2.63	1.57	2.24	1.96	1.85
CM 9	.0297	3.81	.06	3.75	.12	3.69	.18	3.63	.24	3.57	.30	3.51
CM 10	.0890	3.81	.18	3.63	.36	3.45	.53	3.28	.71	3.10	.89	2.92
CM 11	.0519	3.81	.10	3.71	.21	3.60	.31	3.50	.42	3.39	.52	3.29
CM 12	.0914	3.81	.18	3.63	.37	3.44	.55	3.26	.73	3.08	.91	2.90
CM 13	.6845	3.81	1.40	2.41	2.74	1.07	4.11	-.30	5.48	-1.67	6.84	-3.03
CM 14	.1974	3.81	.39	3.42	.79	3.02	1.18	2.63	1.58	2.23	1.97	1.84
CM 15	.0155	1.33	.03	1.30	.06	1.27	.09	1.24	.12	1.21	.16	1.17
CM 16	.0146	1.33	.03	1.30	.06	1.27	.09	1.24	.12	1.21	.15	1.18
CM 17	.0368	1.33	.07	1.26	.15	1.18	.22	1.11	.29	1.04	.37	.96
- CM 18	.0230	1.33	.05	1.28	.09	1.24	.14	1.19	.18	1.15	.23	1.10
UF 1	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50
UF 2	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50
UF 3	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50
UF 4	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50

Appendix C: Continued.

Mgmt. Option Soil Mgmt. Group Combination	Excess Soil-Loss	Current Annual Return	Adjusted Current Annualized Return (CAR) Coefficients ($/Ac./Yr.)							
			Tax Rate = $20		Tax Rate = $40		Tax Rate = $60		Tax Rate = $80	
	(Tn./Ac./Yr)	($/Ac./Yr)	(Tax)	(CAR)	(Tax)	(CAR)	(Tax)	(CAR)	(Tax)	(CAR)
LHN 16	.0140	1.65	.28	1.37	.56	1.09	.84	.81	1.12	.53
LHN 17	.0350	1.12	.70	.42	1.40	-.28	2.10	-.98	2.30	-1.58
LHN 18	.0219	1.12	.44	.68	.88	.24	1.31	-.19	1.75	-.63
CM 1	.0160	3.81	.32	3.49	.64	3.17	.96	2.85	1.28	2.53
CM 2	.0722	3.81	1.44	2.37	2.89	.92	4.33	-.52	5.78	-1.97
CM 3	.0304	3.81	.61	3.20	1.22	2.59	1.82	1.99	2.43	1.38
CM 4	.1738	3.81	3.48	.33	6.96	-3.15	10.43	-6.62	13.90	-10.09
CM 5	.0813	3.81	1.63	2.18	3.25	.56	4.88	-1.07	6.50	-2.69
CM 6	.0610	3.81	1.22	2.59	2.44	1.37	3.66	.15	4.88	-1.07
CM 7	.3388	3.81	6.78	-2.97	13.55	-9.74	20.33	-16.52	27.10	-23.29
CM 8	.1964	3.81	3.93	-.12	7.86	-4.05	11.78	-7.97	15.71	-11.90
CM 9	.0297	3.81	.59	3.22	1.19	2.62	1.78	2.03	2.38	1.43
CM 10	.0890	3.81	1.78	2.03	3.56	.25	5.34	-1.53	7.12	-3.31
CM 11	.0519	3.81	1.04	2.77	2.08	1.73	3.11	.70	4.15	-.34
CM 12	.0914	3.81	1.83	1.98	3.66	.15	5.48	-1.67	7.13	-3.50
CM 13	.6845	3.81	13.69	-9.88	27.38	-23.57	41.07	-37.26	54.76	-50.95
CM 14	.1974	3.81	3.95	-.14	7.90	-4.09	11.84	-8.03	15.79	-11.98
CM 15	.0155	1.33	.31	1.02	.62	.71	.93	.40	1.24	.09
CM 16	.0146	1.33	.29	1.04	.58	.75	.88	.45	1.17	.16
CM 17	.0368	1.33	.74	.59	1.47	-.14	2.21	-.88	2.94	-1.61
CM 18	.0230	1.33	.46	.87	.92	.41	1.38	-.05	1.84	-.51
UF 1	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50
UF 2	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50
UF 3	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50
UF 4	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50

Appendix C: Continued.

Mgmt. Option Soil Mgmt. Group Combination	Excess Soil-Loss	Current Annual Return	Adjusted Current Annualized Return (CAR) Coefficients ($/Ac./Yr.)									
			Tax Rate = $2		Tax Rate = $4		Tax Rate = $6		Tax Rate = $8		Tax Rate = $10	
	(Tn./Ac./Yr)	($/Ac./Yr.)	(Tax)	(CAR)	(Tax)	(CAR)	(Tax)	(CAR)	(Tax)	(CAR)	(Tax)	(CAR)
UF 5	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50
UF 6	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50
UF 7	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50
UF 8	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50
UF 9	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50
UF 10	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50
UF 11	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50
UF 12	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50
UF 13	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50
UF 14	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50
UF 15	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50
UF 16	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50
UF 17	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50
UF 18	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50

Appendix C: Continued.

Mgmt. Option Soil Mgmt. Group Combination	Excess Soil-Loss	Current Annual Return	Adjusted Current Annualized Return (CAR) Coefficients ($/Ac./Yr.)									
			Tax Rate = $20		Tax Rate = $40		Tax Rate = $60		Tax Rate = $80			
	(Tn./Ac./Yr.	($/Ac./Yr.)	(Tax)	(CAR)	(Tax)	(CAR)	(Tax)	(CAR)	(Tax)	(CAR)		
UF 5	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50		
UF 6	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50		
UF 7	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50		
UF 8	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50		
UF 9	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50		
UF 10	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50		
UF 11	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50		
UF 12	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50		
UF 13	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50		
UF 14	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50		
UF 15	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50		
UF 16	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50		
UF 17	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50		
UF 18	0	-1.50	0	-1.50	0	-1.50	0	-1.50	0	-1.50		

APPENDIX D

Appendix D: Current annualized return coefficients adjusted for subsidy on reduced soil loss.

Mgmt. Option Soil Mgmt. Group Combination	Reduced Soil Loss	Current Annual Return	Adjusted Current Annualized Return (CAR) Coefficients ($/Ac./Yr.)									
			Subsidy Rate = $10		Subsidy Rate = $20		Subsidy Rate = $40		Subsidy Rate = $60		Subsidy Rate = $80	
	(Tn/Ac./Yr.)	($/Ac./Yr.)	(Subsidy)	(CAR)	(Subsidy)	(CAR)	(Subsidy)	(CAR)	(Subsidy)	(CAR)	(Subsidy)	(CAR)
SPP 1	0	5.67	0	5.67	0	5.67	0	5.67	0	5.67	0	5.67
SPP 2	0	4.14	0	4.14	0	4.14	0	4.14	0	4.14	0	4.14
SPP 3	0	4.14	0	4.14	0	4.14	0	4.14	0	4.14	0	4.14
SPP 4	0	4.14	0	4.14	0	4.14	0	4.14	0	4.14	0	4.14
SPP 5	0	4.14	0	4.14	0	4.14	0	4.14	0	4.14	0	4.14
SPP 6	0	2.45	0	2.45	0	2.45	0	2.45	0	2.45	0	2.45
SPP 7	0	4.14	0	4.14	0	4.14	0	4.14	0	4.14	0	4.14
SPP 8	0	4.14	0	4.14	0	4.14	0	4.14	0	4.14	0	4.14
SPP 9	0	4.14	0	4.14	0	4.14	0	4.14	0	4.14	0	4.14
SPP 10	0	2.45	0	2.45	0	2.45	0	2.45	0	2.45	0	2.45
SPP 11	0	2.45	0	2.45	0	2.45	0	2.45	0	2.45	0	2.45
SPP 12	0	4.14	0	4.14	0	4.14	0	4.14	0	4.14	0	4.14
SPP 13	0	2.45	0	2.45	0	2.45	0	2.45	0	2.45	0	2.45
SPP 14	0	2.45	0	2.45	0	2.45	0	2.45	0	2.45	0	2.45
MPP 1	.0019	14.77	.02	14.79	.04	14.81	.08	14.85	.11	14.88	.15	14.92
MPP 2	.0084	10.33	.08	10.41	.17	10.50	.34	10.67	.50	10.83	.67	11.00
MPP 3	.0036	10.33	.04	10.37	.07	10.40	.14	10.47	.22	10.55	.29	10.62
MPP 4	.0202	10.33	.20	10.53	.40	10.73	.81	11.14	1.21	11.54	1.62	11.96
MPP 5	.0094	10.33	.09	10.42	.19	10.52	.38	10.71	.56	10.89	.75	11.08
MPP 6	.0071	6.50	.07	6.57	.14	6.64	.28	6.78	.43	6.93	.57	7.07
MPP 7	.0394	10.33	.39	10.72	.79	11.12	1.58	11.91	2.36	12.69	3.15	13.48
MPP 8	.0229	10.33	.23	10.56	.46	10.79	.92	11.25	1.37	11.70	1.83	12.16
MPP 9	.0034	10.33	.03	10.36	.07	10.40	.14	10.47	.20	10.53	.27	10.60
MPP 10	.0103	6.50	.11	6.61	.21	6.71	.41	6.91	.62	7.12	.82	7.32
MPP 11	.0060	6.50	.06	6.56	.12	6.62	.24	6.74	.36	6.86	.48	6.98

Appendix D: Continued.

Mgmt. Option Soil Mgmt Group Combination	Reduced Soil Loss	Current Annual Return	Adjusted Current Annualized Return (CAR) Coefficients ($/Ac./Yr.)									
			Subsidy Rate = $10		Subsidy Rate = $20		Subsidy Rate = $40		Subsidy Rate = $60		Subsidy Rate = $80	
	(Tn./Ac./Yr.)	($/Ac./Yr.)	(Subsidy)	(CAR)	(Subsidy)	(CAR)	(Subsidy)	(CAR)	(Subsidy)	(CAR)	(Subsidy)	(CAR)
MPP 12	.0106	10.33	.11	10.44	.21	10.54	.42	10.75	.64	10.97	.85	11.18
MPP 13	.0796	6.50	.80	7.30	1.59	8.09	3.18	9.68	4.78	11.28	6.37	12.87
MPP 14	.0229	6.50	.23	6.73	.46	6.96	.92	7.42	1.37	7.87	1.83	8.33
LPP 1	.0037	11.94	.04	11.98	.07	12.01	.15	12.09	.22	12.16	.30	12.24
LPP 2	.0168	8.58	.02	8.60	.34	8.92	.67	9.25	1.01	9.59	1.34	9.92
LPP 3	.0071	8.58	.07	8.65	.14	8.72	.28	8.86	.43	9.01	.57	9.15
LPP 4	.0404	8.58	.40	8.98	.81	9.39	1.62	10.20	2.42	11.00	3.23	11.81
LPP 5	.0189	8.58	.19	8.77	.38	8.96	.76	9.34	1.13	9.71	1.51	10.09
LPP 6	.0142	5.63	.14	5.77	.28	5.91	.57	6.20	.85	6.48	1.14	6.77
LPP 7	.0788	8.58	.79	9.37	1.58	10.16	3.15	11.73	4.73	13.31	6.30	14.88
LPP 8	.0457	8.58	.46	9.04	.91	9.49	1.83	10.41	2.74	11.32	3.66	12.24
LPP 9	.0069	8.58	.07	8.65	.14	8.72	.28	8.86	.41	8.99	.55	9.13
LPP 10	.0207	5.63	.21	5.84	.41	6.04	.83	6.46	1.24	6.87	1.66	7.29
LPP 11	.0121	5.63	.12	5.75	.24	5.87	.48	6.11	.73	6.36	.97	6.60
LPP 12	.0212	8.58	.21	8.79	.42	9.00	.85	9.43	1.27	9.85	1.70	10.28
LPP 13	.1592	5.63	1.59	7.22	3.18	8.81	6.37	12.00	9.55	15.18	12.74	18.37
LPP 14	.0459	5.63	1.59	6.09	.92	6.55	1.84	7.47	2.75	8.38	3.67	9.30
SPN 1	.0026	11.80	.03	11.83	.05	11.85	.10	11.90	.16	11.96	.21	12.01
SPN 2	.0118	9.42	.12	9.54	.24	9.66	.47	9.89	.71	10.13	.94	10.36
SPN 3	.0050	9.42	.05	9.47	.10	9.52	.20	9.62	.30	9.72	.40	9.82
SPN 4	.0283	9.42	.28	9.70	.57	9.99	1.13	10.55	1.70	11.12	2.26	11.68
SPN 5	.0132	9.42	.13	9.55	.26	9.68	.53	9.95	.79	10.21	1.06	10.48
SPN 6	.0099	7.23	.10	7.33	.20	7.43	.40	7.63	.59	7.82	.79	8.02
SPN 7	.0052	9.42	.55	9.97	1.10	10.52	2.21	11.63	3.31	12.73	4.42	13.84
SPN 8	.0320	9.42	.32	9.74	.54	10.06	1.28	10.70	1.92	11.34	2.56	11.98

Appendix D: Continued.

Mgmt. Option Soil Mgmt Group Combination	Reduced Soil Loss	Current Annual Return	Adjusted Current Annualized Return (CAR) Coefficients ($/Ac./Yr.)									
			Subsidy Rate = $10		Subsidy Rate = $20		Subsidy Rate = $40		Subsidy Rate = $60		Subsidy Rate = $80	
	Tn.Ac./Yr.)	($/Ac./Yr.)	(Subsidy)	(CAR)	(Subsidy)	(CAR)	(Subsidy)	(CAR)	(Subsidy)	(CAR)	(Subsidy)	(CAR)
SPN 9	.0048	9.42	.05	9.47	.10	9.52	.19	9.61	.29	9.71	.38	9.80
SPN 10	.0145	7.23	.14	7.37	.29	7.52	.58	7.81	.87	8.10	1.16	8.39
SPN 11	.0084	7.23	.08	7.31	.17	7.40	.34	7.57	.50	7.73	.67	7.90
SPN 12	.0149	9.42	.15	9.57	.30	9.72	.60	10.02	.89	10.31	1.19	10.61
SPN 13	.1115	7.23	1.12	8.35	2.23	9.46	4.46	11.69	6.69	13.92	8.92	16.15
SPN 14	.0321	7.23	.32	7.55	.64	7.87	1.28	8.51	1.93	9.16	2.57	9.80
LPN 1	.0045	11.21	.04	11.25	.09	11.30	.18	11.39	.27	11.48	.36	11.57
LPN 2	.0202	9.00	.20	9.20	.40	9.40	.81	9.81	1.21	10.21	1.62	10.62
LPN 3	.0085	9.00	.08	9.08	.17	9.17	.34	9.34	.51	9.51	.68	9.68
LPN 4	.0485	9.00	.48	9.48	.97	9.97	1.94	10.94	2.91	11.91	3.88	12.88
LPN 5	.0226	9.00	.23	9.23	.45	9.45	.90	9.90	1.36	10.36	1.81	10.81
LPN 6	.0170	7.14	.17	7.31	.34	7.48	.68	7.82	1.02	8.16	1.36	8.50
LPN 7	.0946	9.00	.95	9.95	1.89	10.89	3.78	12.78	5.68	14.68	7.57	16.57
LPN 8	.0548	9.00	.55	9.55	1.10	10.10	2.19	11.19	3.29	12.29	4.38	13.38
LPN 9	.0082	9.00	.08	9.08	.16	9.16	.33	9.33	.49	9.49	.66	9.66
LPN 10	.0248	7.14	.25	7.39	.50	7.64	.99	8.13	1.49	8.63	1.98	9.12
LPN 11	.0145	7.14	.14	7.28	.29	7.43	.58	7.72	.87	8.01	1.16	8.30
LPN 12	.0255	9.00	.26	9.26	.51	9.51	1.02	10.02	1.53	10.53	2.04	11.04
LPN 13	.1911	7.14	1.91	9.05	3.82	10.96	7.64	14.78	11.47	18.61	15.29	22.43
LPN 14	.0550	7.14	.55	7.69	1.10	8.24	2.20	9.34	3.30	10.44	4.40	11.54
SHN 15	0	1.99	0	1.99	0	1.99	0	1.99	0	1.99	0	1.99
SHN 16	0	1.99	0	1.99	0	1.99	0	1.99	0	1.99	0	1.99
SHN 17	0	1.13	0	1.13	0	1.13	0	1.13	0	1.13	0	1.13
SHN 18	0	1.13	0	1.13	0	1.13	0	1.13	0	1.13	0	1.13
LHN 15	.0018	1.65	.02	1.67	.04	1.69	.07	1.72	.11	1.76	.14	1.79

Appendix D: Continued.

Mgmt. Option Soil Mgmt. Group Combination	Reduced Soil Loss	Current Annual Return	Adjusted Current Annualized Return (CAR) Coefficients ($/Ac./Yr.)									
			Subsidy Rate = $10		Subsidy Rate = $20		Subsidy Rate = $40		Subsidy Rate = $60		Subsidy Rate = $80	
	Tn./Ac./Yr.	$/Ac./Yr.	(Subsidy)	(CAR)	(Subsidy)	(CAR)	(Subsidy)	(CAR)	(Subsidy)	(CAR)	(Subsidy)	(CAR)
LHN 16	.0017	1.65	.02	1.67	.03	1.68	.07	1.72	.10	1.75	.14	1.79
LHN 17	.0043	1.12	.04	1.16	.09	1.21	.17	1.29	.26	1.38	.34	1.46
LHN 18	.0027	1.12	.03	1.15	.05	1.17	.11	1.23	.16	1.28	.22	1.34
CM 1	.0059	3.81	.06	3.87	.12	3.93	.24	4.05	.35	4.16	.47	4.28
CM 2	.0269	3.81	.27	4.08	.54	4.35	1.08	4.89	1.61	5.42	2.15	5.96
CM 3	.0114	3.81	.11	3.92	.23	4.04	.46	4.27	.68	4.49	.91	4.72
CM 4	.0647	3.81	.65	4.46	1.29	5.10	2.59	6.40	3.88	7.69	5.18	8.99
CM 5	.0302	3.81	.30	4.11	.60	4.41	1.21	5.02	1.81	5.62	2.42	6.23
CM 6	.0227	3.81	.23	4.04	.45	4.26	.91	4.72	1.36	5.17	1.82	5.63
CM 7	.1260	3.81	1.26	5.07	2.52	6.33	5.04	8.85	7.56	11.37	10.08	13.89
CM 8	.0731	3.81	.73	4.54	1.46	5.27	2.92	6.73	4.39	8.20	5.85	9.66
CM 9	.0110	3.81	.11	3.92	.22	4.03	.44	4.25	.66	4.47	.88	4.69
CM 10	.0331	3.81	.33	4.14	.66	4.47	1.32	5.13	1.99	5.80	2.65	6.46
CM 11	.0193	3.81	.19	4.00	.39	4.20	.77	4.58	1.16	4.97	1.54	5.35
CM 12	.0340	3.81	.34	4.15	.68	4.49	1.36	5.17	2.04	5.85	2.72	6.53
CM 13	.2548	3.81	2.55	6.36	5.10	8.91	10.19	14.00	15.29	19.10	20.38	24.19
CM 14	.0734	3.81	.73	4.54	1.47	5.28	2.94	6.75	4.40	8.21	5.87	9.68
CM 15	.0011	1.33	.01	1.34	.02	1.35	.04	1.37	.07	1.40	.09	1.42
CM 16	.0011	1.33	.01	1.34	.02	1.35	.04	1.37	.07	1.40	.09	1.42
CM 17	.0025	1.33	.02	1.35	.05	1.38	.10	1.43	.15	1.48	.20	1.53
CM 18	.0016	1.33	.02	1.35	.03	1.36	.06	1.39	.10	1.43	.13	1.46
UF 1	.0219	-1.50	.22	-1.28	.44	-1.06	.88	-.62	1.31	-.19	1.75	.25
UF 2	.0991	-1.50	.99	-.51	1.98	.48	3.96	2.46	5.95	4.45	7.93	6.43
UF 3	.0418	-1.50	.42	-1.08	.84	-.66	1.67	.17	2.51	1.01	3.34	1.84
UF 4	.2385	-1.50	2.38	.88	4.77	3.27	9.54	8.04	14.31	12.81	19.08	17.58

Appendix D: Continued.

Mgmt. Option Soil Mgmt. Group Combination	Reduced Soil Loss	Current Annual Return	Adjusted Current Annualized Return (CAR) Coefficients ($/Ac./Yr.)									
			Subsidy Rate = $10		Subsidy Rate = $20		Subsidy Rate = $40		Subsidy Rate = $60		Subsidy Rate = $80	
	Tn./Ac./Yr.	$/Ac./Yr.	(Subsidy)	(CAR)	(Subsidy)	(CAR)	(Subsidy)	(CAR)	(Subsidy)	(CAR)	(Subsidy)	(CAR)
UF 5	.115	-1.50	1.12	-.38	2.23	.73	4.46	2.96	6.69	5.19	8.92	7.42
UF 6	.0837	-1.50	.84	-.66	1.67	.17	3.35	1.85	5.02	3.52	6.70	5.20
UF 7	.4647	-1.50	4.65	3.15	9.29	7.79	18.59	17.09	27.88	26.38	37.18	35.68
UF 8	.2695	-1.50	2.70	1.20	5.39	3.89	10.78	9.28	16.17	14.67	21.56	20.06
UF 9	.0407	-1.50	.41	-1.09	.81	-.69	1.63	.13	2.44	.94	3.26	1.76
UF 10	.1221	-1.50	1.22	-.28	2.44	.94	4.88	3.38	7.33	5.83	9.77	8.27
UF 11	.0712	-1.50	.71	-.79	1.42	-.08	2.85	1.35	4.27	2.77	5.70	4.20
UF 12	.1254	-1.50	1.25	-.25	2.51	1.01	5.02	3.52	7.52	6.02	10.03	8.53
UF 13	.9393	-1.50	9.39	7.89	18.79	17.29	37.07	36.07	56.36	54.86	75.14	73.64
UF 14	.2708	-1.50	2.71	1.21	5.42	3.92	10.83	9.33	16.25	14.75	21.66	20.16
UF 15	.0166	-1.50	.17	-1.33	.33	-1.17	.66	-.84	1.00	-.50	1.33	-.17
UF 16	.0157	-1.50	.16	-1.34	.31	-1.19	.63	-.87	.94	-.56	1.26	-.24
UF 17	.0393	-1.50	.39	-1.11	.79	-.71	1.57	.07	2.36	.86	3.14	1.64
UF 18	.0246	-1.50	.25	-1.25	.49	-1.01	.98	-.52	1.48	-.02	1.97	.47

GLOSSARY

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Basal Area: The area, usually expressed in square feet, of the cross section at breast height of a single tree or of all trees in a stand. This is usually inside bark unless otherwise stated.

Commercial Forest Land: Forest land producing or capable of producing crops of industrial wood and not withdrawn from timber utilization.

Cutting Cycle: The planned interval between major felling operations in the same uneven-aged stand.

Growing Stock: Net volume in cubic feet of all live trees of commercial species which are at least 5.0 inches in diameter at breast height, from a 1-foot stump to a minimum top diameter of 4.0 inches outside bark of the central stem, or to the point where the central stem breaks into limbs.

Physiographic Site: A classification of forest land according to its suitability for growing certain species groups -- pines, upland hardwoods, or bottomland hardwoods.

Poletimber: Growing stock trees of commercial species at least 5.0 inches in diameter at breast height, but smaller than sawtimber size.

Prescribed Burning: Controlled application of fire to wildland fuels in either their natural or modified state, under such conditions of weather, fuel moisture, soil moisture, etc. as to allow the fire to be confined to a predetermined area and at the same time to produce the intensity of heat and rate of spread required to further certain planned objectives of silviculture, wildlife management, grazing, fire hazard reduction, etc.

Raking: The process of removing all residual woody material from a harvest site and either pushing it into rows or piles with the use of a bulldozer fitted with a rake attachment on the bulldozer blade.

Roller Chopper: An implement with blades mounted on a horizontal power driven shaft, for reducing the bulk of slash after felling and so facilitating planting.

Rotation: The number of years required to establish and grow timber crops to a specified condition of maturity.

Saplings: Live trees of commercial species, 1.0 inch to 5.0 inches in dbh and of good form and vigor.

Sawtimber: Live trees that are of commercial species, contain at least one 12-foot saw log, and meet regional specifications for freedom from defect. Softwoods must be at least 9.0 inches in dbh and hardwoods at least 11.0 inches.

Shearing: The process of cutting off all residual vegetation at the ground line (after a harvest operation) by using a bulldozer equipped with a special cutting blade.

Site Index: The average height of the dominant and codominant trees in a stand at some specified base age, such as 25 or 50 years. It is a measure of site quality.

Stocking: An indication of the number of trees in a stand as compared to the desirable number for best growth and management -- such as well-stocked, over-stocked, or partially stocked.

Thinning: A cutting made in an immature stand in order to stimulate the growth of the trees that remain and to increase the total yield of useful material from the stand. A commercial thinning would be one in which the trees removed are of merchantable size and the total volume is sufficient to at least cover the costs of harvesting. A precommercial thinning would be one in which the trees removed are not of merchantable size.

Weeding: An operation in a young stand, not past sapling stage (1) to free small trees as in plantations from weeds, vines or sod-forming grasses, and (2) to provide better growing conditions by liberating crop trees from other individuals of similar age but of less desirable species or form which are overtopping or likely to overtop them.